TM 5-331E

DEPARTMENT OF THE ARMY TECHNICAL MANUA

UTILIZATION OF ENGINEER CONSTRUCTION EQUIPMENT

VOLUME B-LIFTING, LOADING, AND HAULING EQUIPMENT

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DEPARTMENT OF THE ARMY
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UTILIZATION OF ENGINEER CONSTRUCTION EQUIPMENT

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*This manual supersedes chapters 8, 9, and paragraph 142 of TM 5-331, 30 November 1962.

CHAPTER 1

GENERAL

Section I. INTRODUCTION

1-1. Purpose and Scope

a. This manual furnishes information and guidance to personnel responsible for utilizing and supervising the operation of engineer construction equipment. It includes the characteristics, capabilities, and use of equipment for typical construction tasks; guides for estimating the output of various items of equipment; safety practices; and expedient equipment for specific construction tasks.

b. The information contained herein is applicable without modification to both nuclear and non-nuclear warfare.

1-2. Subdivision Into Volumes

This manual is composed of five volumes dealing with engineer equipment groupings as follows:

Volume A—Earthmoving, Compaction, Grading and Ditching Equipment

Volume B—Lifting, Loading, and Hauling Equipment

Volume C—Rock Crushers, Air Compressors, and Pneumatic Tools

Volume D—Asphalt and Concrete Equipment

Volume E—Engineer Special Purpose and Expedient Equipment

1-3. Recommended Changes

Users of this manual are encouraged to submit recommended changes or comments to improve it. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded directly to the Commandant, U.S. Army Engineer School, Fort Belvoir, Va. 22060.

Section II. BASIC CONSIDERATIONS

1-4. Management

To obtain maximum effectiveness from men and equipment, modern techniques as well as the fundamentals of management must be utilized. The latter take in planning, scheduling, supervision, and job control, while the former include project analysis and program evaluation and review technique (PERT). Thus, this manual should be used in conjunction with TM 5-333, Construction Management, and the appropriate technical manual for the particular construction task being accomplished. Detailed information for any particular model of equipment mentioned in this manual may be obtained in the appropriate -10 series technical manual for that model.

1-5. Need for Maintenance

Equipment maintenance and equipment operation are reciprocal functions; one has a direct effect upon the other. Thus, in order to accomplish a construction mission in the minimum possible time, the construction unit must have and maintain a high state of maintenance of its equipment. Improper organizational maintenance is the cause of many equipment fail-

ures. These failures normally occur when the equipment is used the hardest or when the equipment is needed the most.

1-6. The Equipment Pool

Operator maintenance is done before, after, and during each shift or operation as required. As equipment pool is established adjacent to the job site in a central location. An organizational maintenance team should be available to assist the operators as necessary during regularly scheduled operator maintenance. Necessary fuels, lubricants, and water should be easily accessible to the operator in the equipment pool. The utilizing team supervisor should be present during the conduct of operator maintenance to insure proper maintenance and to assist the operator in obtaining higher support maintenance when required.

1-7. Organizational and Direct Support Maintenance

Organizational and direct support maintenance can be performed in the field. The size of the job indicates where the maintenance shops will be located. On company-size jobs, the organizational maintenance is normally moved to the job site. Similarly, for battalion size jobs the organic direct support maintenance shop is normally moved to the job site to give better and faster maintenance support to the utilizing teams. On smaller jobs, however, the company will have equipment in several locations and only organizational contact teams will be available intermittently. In such cases, periodic maintenance is normally performed at the centrally located organizational shop, which requires transporting the equipment to the organizational shop. In any case, however, the mission of the higher support maintenance organizations is to support the utilizing teams. The utilizing team should keep the higher category of maintenance informed of any deficiencies noted on its equipment.

1-8. Operator Training

For a number of reasons, Army units continually receive new men. Since these men are not always familiar with the equipment organic to the unit, new operators must often be trained. A training program should be set up which will insure proper operation and maintenance of the unit's equipment. The quality of an operator's training will always be reflected in his output. When a single operator must be trained, he can be assigned to one of the better operators for individual training following a prescribed program. When a large number of operators must be trained, a more formal program should be set up. For further information see AR 58-1, AR 385-40, AR 385-55, AR 600-55, AR 600-58, and TM 21-305. Only after an operator has been properly trained and then given adequate supervision can he be expected to obtain maximum efficiency.

CHAPTER 2

CRANES, CRANE-SHOVELS, AND ATTACHMENTS

Section I. GENERAL

2-1. Introduction

a. A major task in any construction operation is the handling of construction supplies and excavating. The major portion of this work is done by equipment of the lifting and loading family. Included in this family are the crane and crane-shovel. The crane-shovel with its variety of front-end attachments is the most common kind of lifting and loading equipment.

b. The basis crane-shovel unit consists of a carrier or mounting either crawler or truck mounted, and revolving superstructure or upper revolving frame. Although the superstructure is substantially the same on all makes and models, the carrier or mounting may be one of three types: crawler, truck, or wheel (fig. 2-1). In order to make the basic unit complete and operable, any one of six attachments may be installed. Once an attachment is installed the entire unit acquires the name of the attachment: crane (hook), clamshell, piledriver, dragline, backhoe or shovel (fig. 2-2).

c. Although crane-shovels are available in varied sizes and capacities, and include sizes of over 100 cubic yards, the military crane-shovels range between 5 tons, $3/8$ cubic yard and 68 tons, $3\frac{1}{2}$ cubic yards.

2-2. Crawler Mountings

The crawler mounting provides a stable base for the operation of the revolving superstructure, low ground bearing pressure and excellent on-the-job maneuverability.

The weight of the machine is spread over a large area due to the size of the crawler threads. The crawlers are powered with either diesel or gasoline engines and are capable of

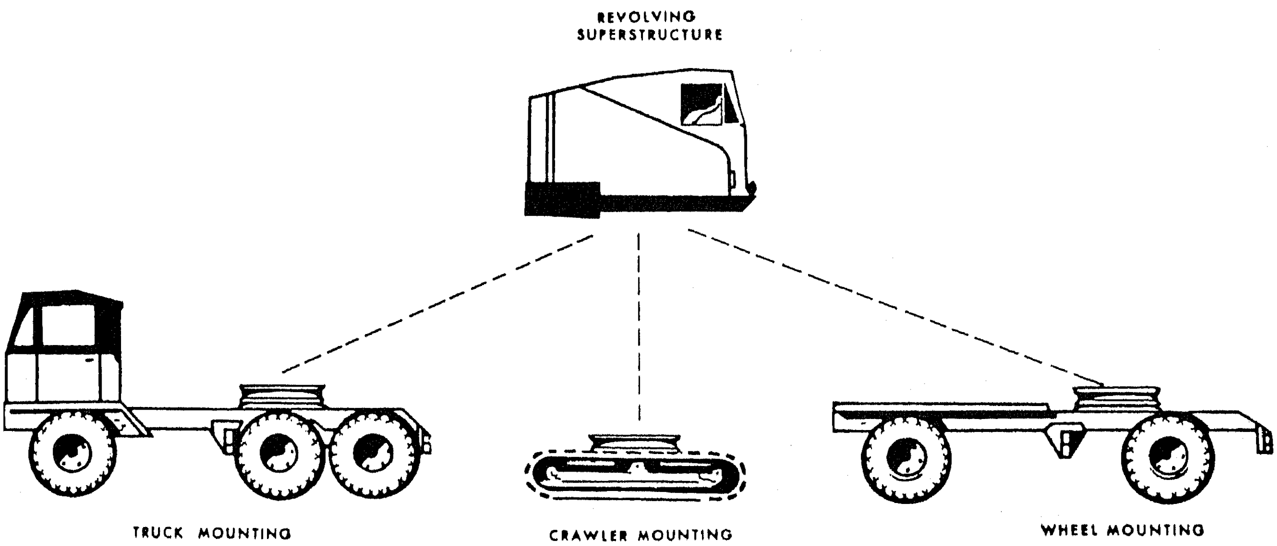


Figure 2-1. Mountings for the crane-shovel.

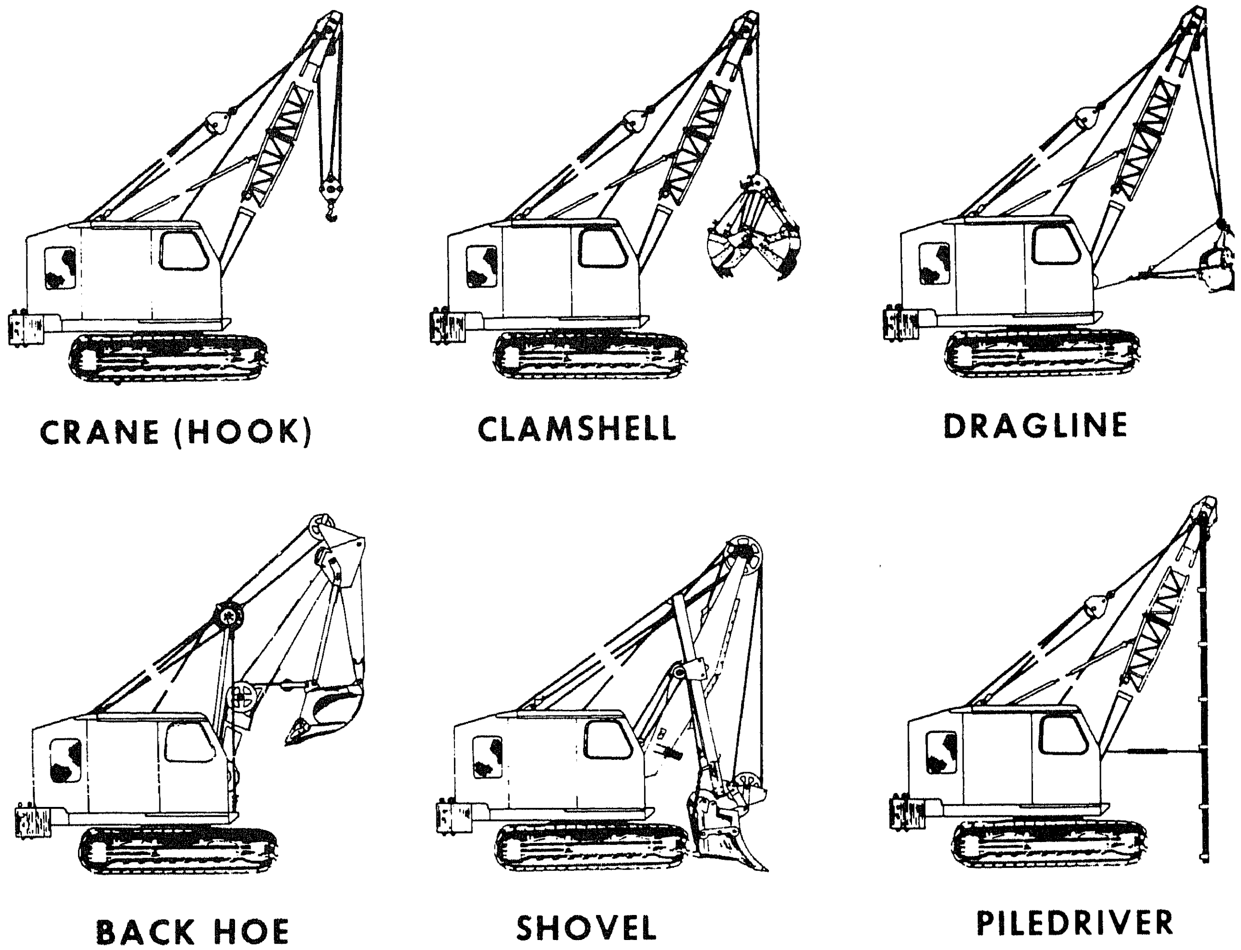


Figure 2-2. Crane-shovel attachments.

speeds up to 2 miles per hour. They have the ability to climb grades up to 30 percent on firm dry ground and can travel through softer ground than other mountings because of their 5 to 12 pounds square inch (psi) ground bearing pressure. In locations where the ground is soft or unstable, construction mats (wood) are used to provide firm footings (fig. 2-3). Transport by low bed trailer is necessary for distances greater than one mile due to the relatively low travel speeds and excessive wear and strain on the tracks. As a normal rule the crawler is employed on a job which will last a long time. The crawler mounting can be used to operate in water as long as the water does not get inside the revolving superstructure. Before moving in water, operators must check for depths, soft areas, and dangerous holes to avoid mishaps during the operation. Crawler machines steer by disengaging the power to one track and engaging the power to the other. Some cranes have no brakes and there is a possibility of disengaging power from both tracks resulting in the machine being free-wheeling, therefore extra precaution must be exercised when moving the crawler on slopes.

2-3. Truck Mountings

Truck type mountings are specially designed heavy duty motor trucks. The truck has a separate engine for propulsion. This mounting provides a less stable base (70 to 100 psi), higher ground bearing pressures and poorer on-the-job mobility than the crawler mounting,

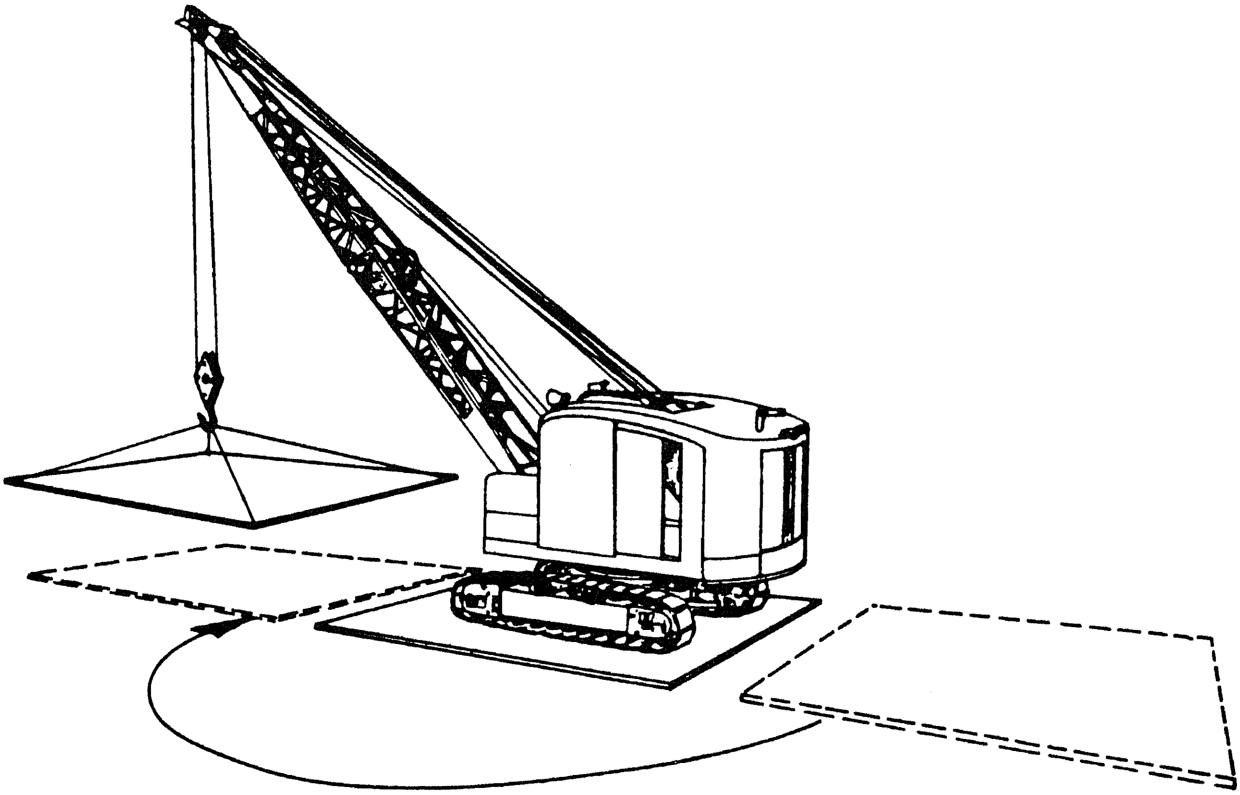


Figure 2-3. Two construction mats supporting crane-shovel in soft material.

but has excellent inter-job mobility. There are springs under the front of the truck but none under the rear. The carrier is equipped with two outriggers (crawlers have no outriggers) on each side to improve stability during operation of the crane or other attachments. The mountings have a transmission providing five to nine speeds forward, two-speed transfer case giving ten to eighteen speeds forward, and a two-speed reverse. The maximum highway speed is approximately 35 miles per hour.

Truck mounting restricts the efficient use of these cranes to firm, level terrain. A pintle hook (towing connection) is located on the rear and towing eyes on the front of the mounting. The pintle hook enables the machine to tow the 10-ton tandem wheel attachment trailer thereby allowing the one piece of equipment to transport all basic attachments to the job site as required. The towing eyes will withstand twice the dead weight pull of the vehicle and are used to attach an assisting vehicle to the machine to tow the carrier if the engine is inoperable or if the carrier is stuck or mired down. Generally, lifting should not be performed over the front because of poor visibility and the possibility of damage to the front suspension system. Heavy lifting should be done over the rear of the truck because there are no springs in the rear and the truck cab and engine provide additional counterweight for the load. Stability may be increased by extending the outriggers and screwing the jacks down securely on the base plates. The base plates should be checked periodically to insure that proper bearing upon the soil is being maintained. The truck transmission should always be placed in neutral during superstructure operation to prevent possible damage to the gears through any rocking movement of the truck.

2-4. Wheel Mountings

a. Rough Terrain Crane (4 x 4).

(1) *Components.* The rough terrain 20-ton crane (fig. 2-4) is powered by two diesel engines—an eight-cylinder engine in the carrier and a six-cylinder engine in the revolving superstructure. The carrier has a utility (dozer) blade mounted on the front, and two outrigger assemblies on each side. Both the outriggers and the blade are operated hydraulically from the driver's cab on the carrier. The four large earthmoving type tires can all be driven. The carrier is steered hydraulically with the choice of three positions or methods; conventional two-wheeled steering, four-wheeled steering, and crab steering. The carrier transmission has four forward speeds or four reverse depending on the position of the directional control lever. The machine has a torque converter drive.

(2) *Characteristics and capabilities.* The ground bearing pressure of the carrier is approximately 55 psi, resulting from the machine's large tires. This low pressure enables the machine to travel over relatively soft terrain. The travel speed of the machine is 30 miles per hour on the highway, and it can traverse slopes up to 48 percent on firm dry ground. The pintle hook on the rear of the carrier enables it to tow the 10-ton tandem wheel attachment trailer. However, it is not recommended to tow the trailer cross-country. With the dozer blade the machine can make a roadway for cross-country operation. The blade can also be used to level a site on which the crane can operate. The blade can be used to knock down trees up to 10 inches in diameter—larger trees will bend the blade as the blade is not intended for heavy duty work. The boom should be positioned to the rear when the blade is being used to knock down trees to prevent it being damaged. Since the carrier is not suspended on springs, the front axle must oscillate. This oscillation prevents the carrier from tipping if one of the front wheels drops off in a hole. The general difference between this item and the truck-mounted crane is its special design for high mobility, making it available for employment in areas inaccessible to the truck mounted crane.

(3) *Techniques of operation.* When at all possible, the machine should be raised completely off the ground on the outriggers. This removes the instability caused by the rubber tires. The outriggers are operated individually, thus the complete machine can be leveled. If the machine is not raised on the outriggers

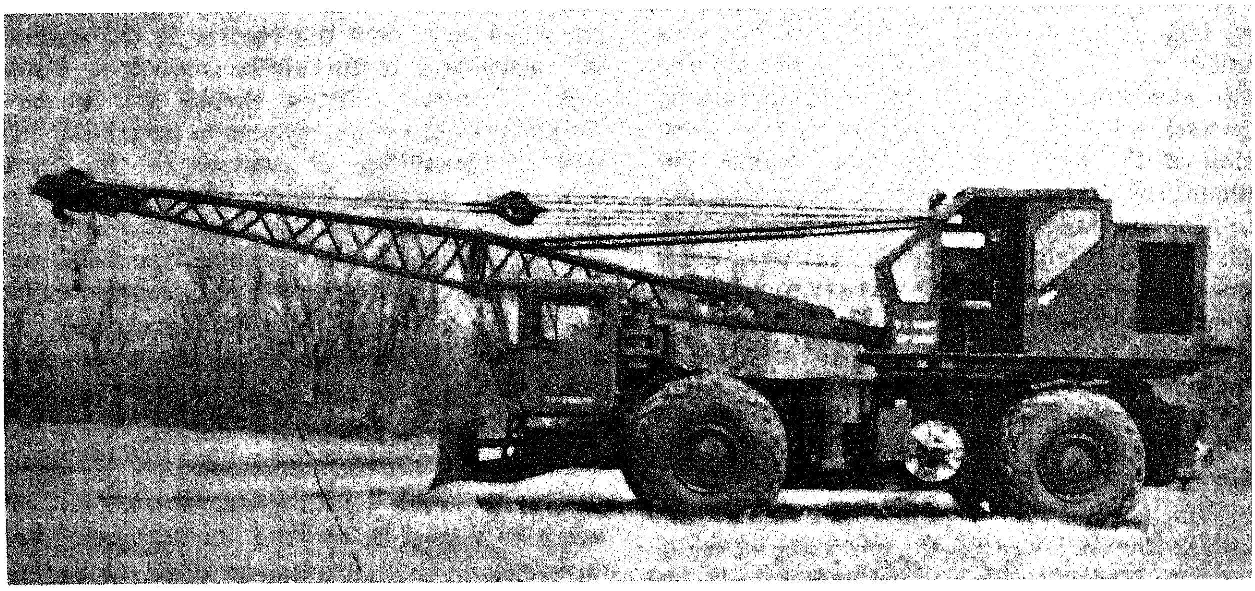


Figure 2-4. Rough terrain crane.

then wedges must be positioned on the front axle to prevent oscillation.

b. Airborne Crane. The 7-ton airborne crane is wheel mounted on rubber tires and has a high ground bearing pressure of from 70 to 100 psi thereby necessitating relatively firm terrain for its use. It is a single-engine machine in which the engine mounted on the turntable is used to power and operate all functions of the turntable and boom equipment and furnish power to propel the carrier. This unit can travel at 8 miles per hour under its own power and traverse slopes of 40 percent on firm dry terrain. The carrier is equipped with a towing tongue on the front and can be towed at 30 miles per hour thus enabling it to be moved in a convoy. The boom is a 24-foot open lattice type boom. The attachments available are the hook block, the clamshell, and the dragline. The carrier is equipped with two outriggers on each side to improve stability.

2-5. Revolving Superstructure

The revolving superstructure rests on the mounting, or carrier, and includes the counterweight, engine, operating mechanism, boom hinge brackets, and usually a cab.

a. Counterweight. The counterweight is normally a cast steel member that is bolted to the rear of the superstructure. The army employs two different types of counterweights. Each type is used for operation of different front-end attachments. On some makes, lead puncheons are made which can be placed in a metal box between the engine and "A" frame for attitional counterweight. Only so much weight can be lifted with the boom, as the rear end or counterweight will balance. If too much weight is lifted the machine will tip forward because it loses its forward stability. It is also true that if too much counterweight is used a machine may lose its backward stability and tip over backwards. This is especially true when heavy loads are dropped or released suddenly. In cases of excess counterweight the machine may tip over backwards when the boom is removed. The danger of losing backward stability is the main resaon for not producing a greater lifting capacity by adding more and more counterweight at the rear.

b. Engine. Engines used in crane shovel units are either gasoline or diesel and are usually six-cylinder types, Machines ranging from 3/8 to 3/4 cubic yard bucket capacities are usually powered with gasoline engines while those with 1 to 3½ cubic yard capacities are normally powered with diesel engines. A formula for estimating the approximate gasoline or diesel fuel consumption is given below:

$$\frac{\text{BHP} \times \text{Factor} \times \text{Pounds Fuel Per Hour}}{\text{Weight of Fuel Per Gallon}} = \text{Gallons Per Hour}$$

Where:

BHP = Brake HP of engine, or rated HP

Factor = efficiency = 50–60%

Pounds fuel per brake horsepower hour:

gasoline 0.7

diesel 0.5

Weight of fuel in pounds per gallon:

gasoline 6.2

diesel 7.3

From the above formula an approximate gaso line consumption of 0.056 to 0.068 gallons pe horsepower hour (GPHPH) is obtained baseu on 50 or 60 percent factor respectively. It is suggested to use an average of about 0.06 GPHPH. Diesel fuel consumption is about 0.034 to 0.041 GPHPH and it is suggested to use an average of 0.040. The above approximate fuel consumption figures are based on normal operations at normal altitudes above sea level and horsepower developed. For high altitudes the consumption is in proportion to the horsepower developed. Shovels normally will consume a greater amount of fuel than the other types of machines considered. Therefore, the larger consumption rate indicated should be used for estimating fuel for shovels and the smaller rate for dragline and clamshell machines. Machines used only for crane service usually operate intermittently, and fuel consumption is difficult to estimate but is generally not an important consideration.

c. Operating Mechanisms. Two independent cable drums are used to control the operation

of the various attachments. The drums may be mounted in line with each other or one behind the other. They will generally be referred to according to their relative mounting, such as right or left, front or rear. The drums may also be referred to according to the function of the drum in controlling a particular attachment. An example of this is the drag cable drum during dragline operation and the closing line cable drum during clamshell operation. The drum that is used in conjunction with the crane hook block will usually be referred to as the rear or main hoist drum. Crane-shovel units are equipped for hoisting the boom as well as operating the attachment. A third drum, the boom hoist drum, controls the raising or lowering of the boom. On some models a two-piece grooved drum lagging is provided for quick attachment to the front drum shaft. This lagging replaces the split type sprocket that is used on the front drum shaft for shovel operation. The grooved lagging are of different diameters depending on the make and model of the machine. The differences in diameter provide different line speeds. An example is the lagging used for dragline operation which may be smaller to provide a slower line speed, thereby giving greater power. Clutches and brakes may be powered mechanically, hydraulically, or pneumatically. On some makes and models the clutches are the internal expanding type, which are internally mounted and, when actuated, expand to drive the drum. Other makes and models have external contracting type clutches.

d. Lighting. On some makes and models of crane-shovels the lighting system is powered by a separate engine driven light plant. On other the lighting system is powered by the main engine electrical system. Each system provides a trouble light extension cord to enable the operator and/or maintenance personnel to work on components within the cab of the superstructure. Neither system provides adequate lighting for efficient night operations. In addition, for crane work, the light provided does not illuminate enough of the shadows to allow the operator and the riggers to work with a high degree of safety.

Section II. CRANES

2-6. Introduction

Cranes are units used primarily for lifting an object or load, transferring it to a new location by swinging or traveling, and then placing the load in the new location. The types of loads that can be handled are determined by the type of accessories that are available for use on the hook. These accessories include, but are not limited to, slings, concrete buckets and magnets.

2-7. Lattice-Boom Crane

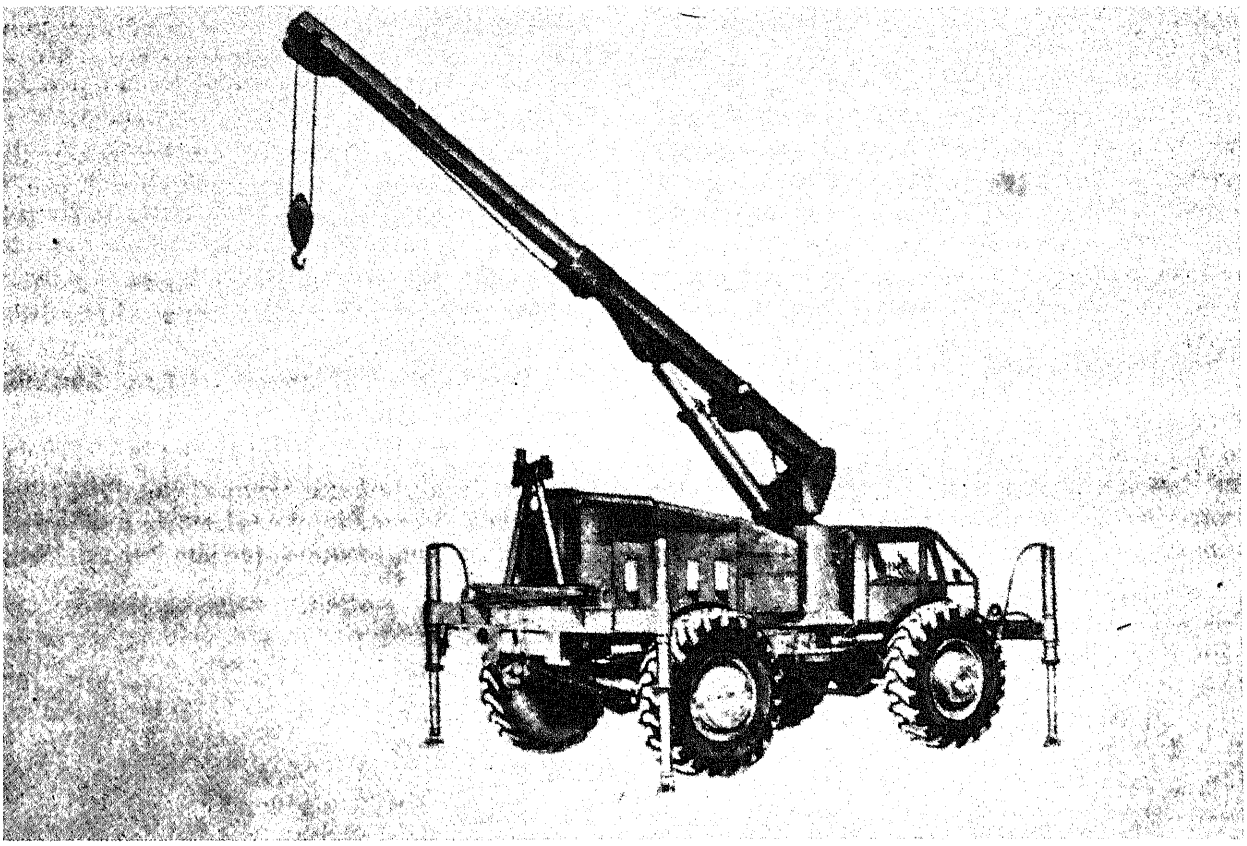
The boom of this crane is usually made in two sections fastened approximately in the center by one of two methods; bolted butt plate (flange) connection or pin and clevis connections. The upper section with the boom head and a system of sheaves is usually but not necessarily the same length as the lower section. Basic crane equipment includes hoist drums, hook block to provide the required parts of line (reeving), and the boom suspension and hoist wire ropes. Older models may also include laggings for desired line pulls and speeds.

2-8. Hydraulic Crane

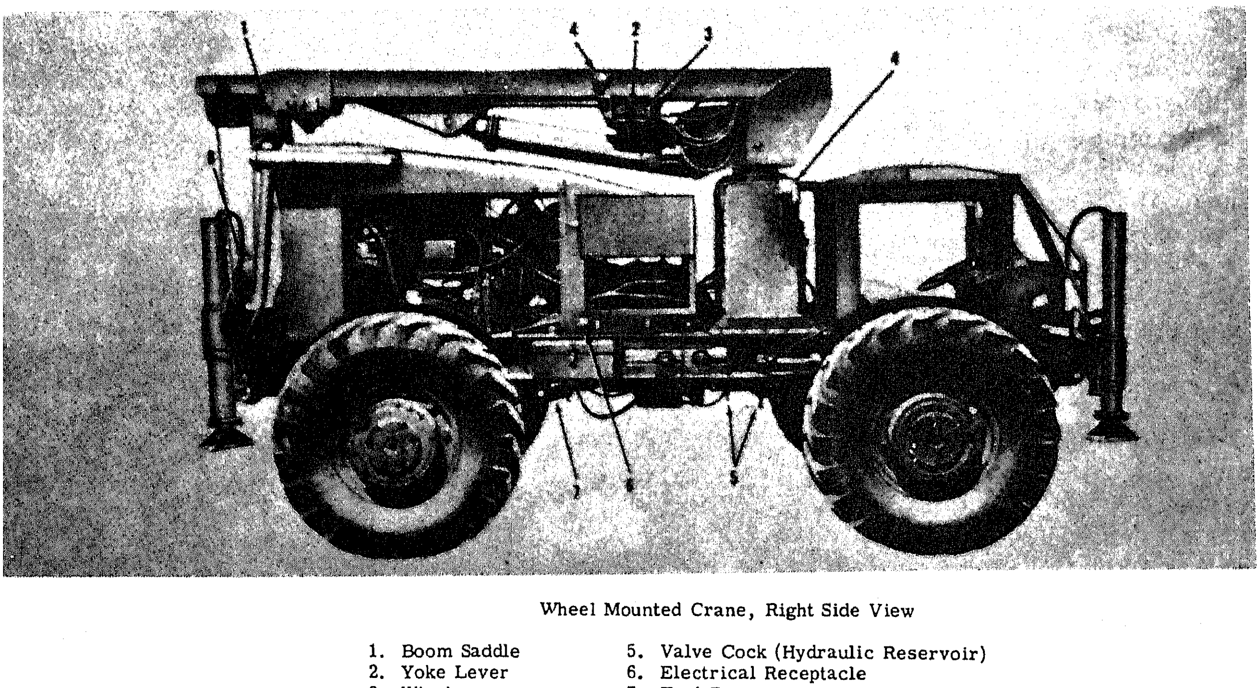
a. Introduction. A hydraulic crane consists essentially of a 4-wheel-drive, 4-wheel-steer, pneumatic tired, diesel-engine-powered carrier, with a center-mounted boom. Some hydraulic cranes are also derived from such other basic units as the loader, scoop, and the rough-terrain forklift truck.

b. Crane, Wheel Mounted, Anthony Model M-60.

(1) *Components.* The model M-60 wheel-mounted crane (fig. 2-5) is a four-wheel drive, hydraulically operated crane designed for off-road operation. The crane is constructed in five sections designed for disassembly, transportation by air, and rapid reassem-



Three-quarter Rear View of Crane, Boom Extended



Wheel Mounted Crane, Right Side View

1. Boom Saddle
2. Yoke Lever
3. Winch
4. Floodlights
5. Valve Cock (Hydraulic Reservoir)
6. Electrical Receptacle
7. Tool Box
8. Hook Block

Figure 2-5. Wheel mounted crane M-60.

bly at the point of intended use. The transmission is mounted so that front-wheel drive is normally used. The steering can be operated as two wheel, four wheel, or crab steering. The front axle is rigid and bolted directly on the frame and the rear axle oscillates the same as the rough terrain crane's front axle. The machine is center-pin mounted and rated at 3 tons. It is equipped with hydraulically operated outriggers which may be extended 17 inches to the side and have a 30-inch vertical stroke.

(2) *Characteristics and capabilities.* An 18-foot boom is mounted behind the cab. The boom, which is hydraulically operated from the operator's seat or from the front of the crane, has a retracted length of 10½ feet and a maximum capacity of 3 tons. The boom may be moved in three planes, rotated through a horizontal arc of 280°, raised through a vertical arc of 75°, and extended from 10½ to 18½ feet. There is also a 5-foot boom extension which can increase the boom length to 23½ feet. This piece of equipment has a ground bearing pressure of approximately 35 psi. It can travel at speeds up to 30 miles per hour, traverse slopes of 40 percent on firm dry terrain, and can ford bodies of water up to 60 inches deep without application of a deep-water fording kit.

c. Crane, Wheel-Mounted, 5-Ton, 3/8-Cubic Yard. Rough Terrain.

(1) *Components.* The 5-ton (10,000 pound) rough-terrain crane (fig. 2-6) is a four-wheel drive, four-wheel steer, pneumatic-tired, diesel engine-powered item with a front-

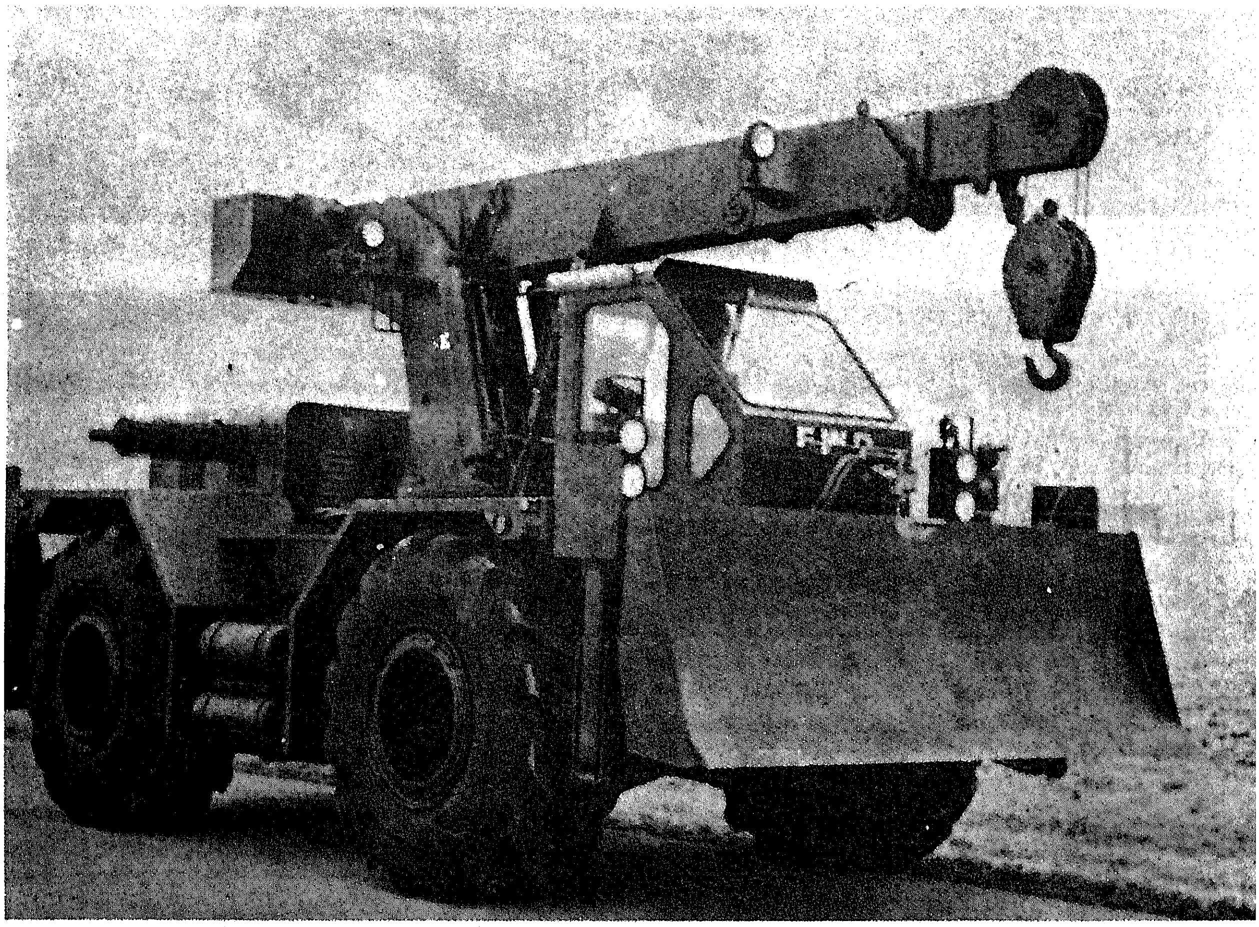


Figure 2-6. Wheel-mounted, 5-ton, 3/8-cubic yard, rough-terrain, crane.

end-mounted, hydraulically operated dozer blade and rear-end pintle hook.

(2) *Characteristics and capabilities.* The crane equipped with the basic boom is adaptable to and operable as a ⅜-yard capacity hydraulically operated clamshell. It is also capable without load and with blade attached to traverse 15-percent side slopes, and has the rated lifting capability shown in table 2–1.

Table 2–1. 5-Ton. Rough Terrain Rated Load Lifting Capacities

	Pounds
With outriggers, 10-foot operating radius*	10,000
With outriggers, boom fully extended, 24-foot operating radius.	5,400
Vehicle mounted on rubber, outriggers retracted, axles locked, 15-foot operating radius.	4,800
With outriggers, 15-percent side slope, 24-foot operating radius.	2,000
With outriggers, 15-percent side slope, 25-foot operating radius.	-----

* Boom radius is the measured distance from a point on the centerline of rotation of the revolving superstructure to the centerline of the crane block with load suspended.

The physical characteristics are listed in table 2–2.

Table 2–2. Physical Characteristics of 5-Ton, 3/8-Cubic Yard Rough-Terrain Crane

Dimensions	*Feet*
Overall width	9.8
Overall length (with boom), maximum	26.7
Overall length (without boom and dozer blade), maximum.	19.9
Overall height, maximum	11.0
Wheelbase, minimum	8.6

d. Crane Attachment, Truck-Mounted, Hydraulic Powered Winch, 5,500-Pound for Rough Terrain Forklift.

(1) *Components.* The crane attachment designed for use with the 10,000-pound rough-terrain forklift crane consists of a rotary power unit assembly, winch assembly, hydraulic brake cylinder, boom assembly, wire rope assembly, crane block and sheaves, crane hook, two boom support stiff leg assemblies, two stiff leg support weld braces, a winch motor assembly, two winch motor-to-truck hose assemblies, two rotary power units-to-truck hose assemblies, two relief valves, and a winch brake cylinder-to-truck hose assembly.

(2) *Capabilities.* Power for operation of the crane attachment is supplied by hydraulic oil that is under pressure from the crane's main hydraulic pump. Hydraulic tubes and hose assemblies transfer this pressure to the crane attachment. This unit with stiff legs is capable of lifting 6,400 pounds in a straight ahead position; it can traverse 180° with 5,500 pounds; and it can traverse 2,000 pounds 180° without stiff legs. When the attachment is dismounted from the crane, it is supported by a crane stand assembly designed especially for this purpose. For additional information regarding this attachment, see Technical Manuals 10–3930–218–10 through 50.

2–9. Factors Affecting Lifting Capacities

All cranes, regardless of size, are rated on the maximum safe lifting capacity based on the following: boom length, operating radius or boom angle, type of footing, use of outriggers, amount of counterweight size of hook block, construction and size of wire rope, position of lift, and the overall maintenance condition of the crane.

a. Boom Length. The standard lengths of the lattice boom can be increased by two methods. The most common method is to insert intermediate center sections between the upper and lower sections. The second method is to add a boom tip extension called a jib. The jib is similar in construction to the standard boom but is much shorter (15 to 30 feet). This extension may be used as a straight continuation of the main boom or may be offset from the boom centerline to provide greater horizontal reach. However, some crane booms are not equipped with jib boom anchor plates and therefore can use only the center section for extending the boom. When lattice booms are lengthened, the gantry or "A" frame must be extended in order to provide an efficient lifting angle for the boom lines. Crane lifting capacities are reduced when boom lengths exceed the normal or standard boom length.

Capacity is further reduced when using the boom jib attachment on the lattice type. This is due to the increased moment arm or operating radius and the added weight of the additional boom sections.

b. Operating Radius. Radius is defined as the horizontal distance measured from the axis of rotation of the cab to a vertical line extending down from the outside edge of the crane boom head sheave. Lifting cranes are rated according to lifting capacities at various radii. A crane is rated on the maximum load it is capable of lifting. The basis of such a classification is as follows:

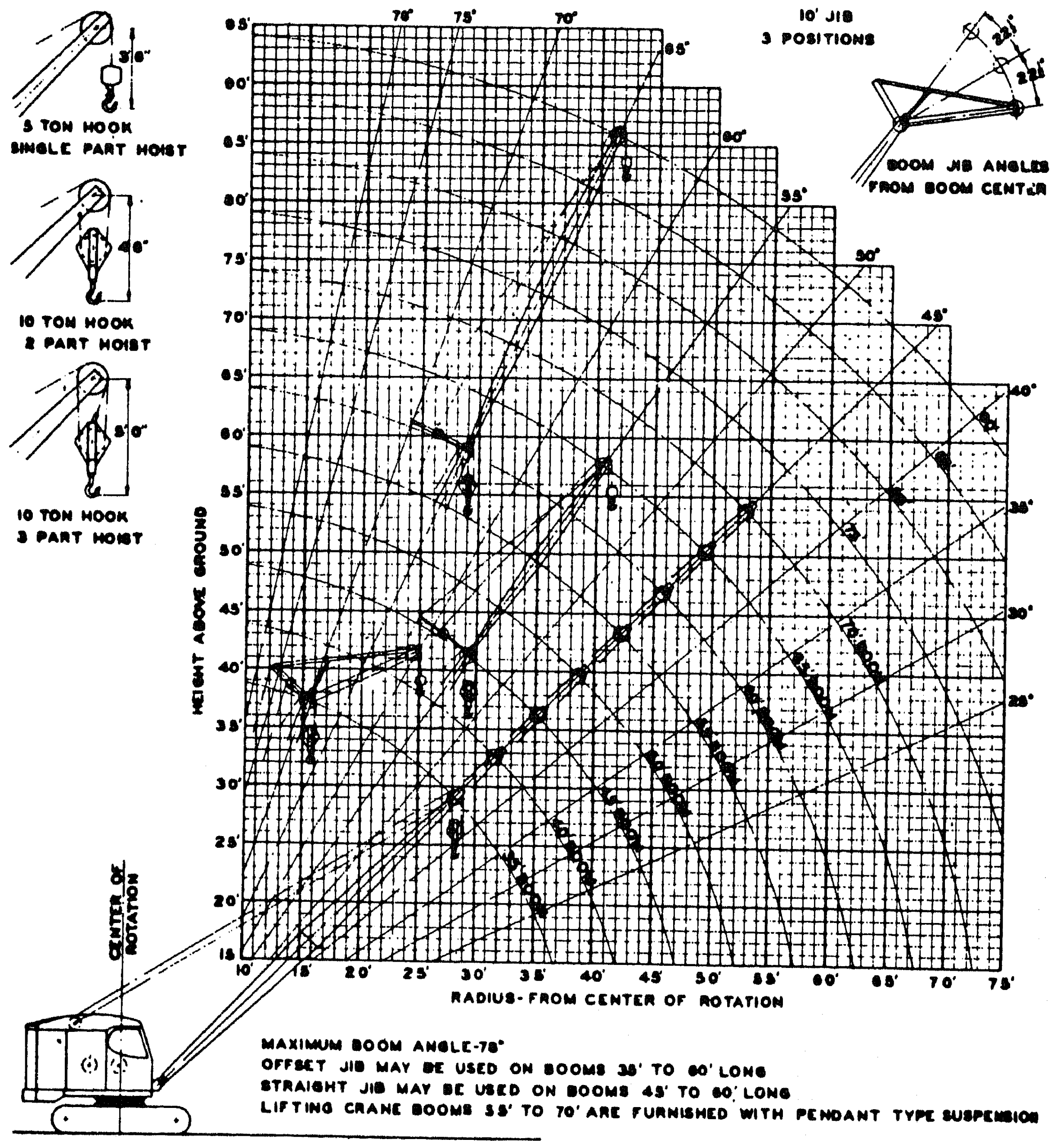


Figure 2-7. Working range dimensions for 10-ton crawler crane.

(1) Crawler cranes are classified and identified by their rated lifting capacity at 12-foot radius, with specified length of boom. This means that a 10-ton crawler crane will lift 10 tons at a 12-foot radius, but not at any greater working radius.

(2) Truck-mounted cranes are classified and identified by their rated lifting capacity at 10-foot radius, with outriggers set, and with specified length of boom. This means that a 20-ton truck crane will lift 20 tons at a 10-foot radius, but not at any greater working radius. The weight of the load should be determined particularly where boom swing is necessary. Unless the weight of the load is known it should be lifted initially in the least stable position which is usually off the side of the carrier. As the working radius increases, the lifting capacity decreases.

c. Type of Footing. It is extremely important that the crane be positioned on firm and level material to prevent accidental tipping. The footing must be kept firm and level not only to prevent tipping but to reduce excessive stresses on the machine. If necessary the site where the crane is to be positioned should be prepared in advance.

d. Machine Stability. Cranes can be made stable by one of two methods: proper use of outriggers on the truck-mounted crane, and the use of heavy counterweights on the crawler-mounted crane. In order to prevent structural damage to the equipment, care should be exercised to prevent the use of too much counterbalance and anchoring the equipment to a "deadman".

e. Hook Block. The hook block used on the crane should be of the size prescribed for the crane. Although other sizes of blocks can be used, the block and sheave system may be damaged through lack of proper rigging and hook capacity. Tables of lifting capacities usually do not include allowances for the weight of the hook block being used, therefore it must be added into the overall weight being lifted.

f. Position of Lift. The crane is capable of heaviest lifting when the boom and load are positioned in line with the longitudinal axis of the carrier or mounting. Therefore with the same operating radius and the boom positioned at right angles to the carrier, the maximum weight lifted must be reduced, otherwise a tipping condition will occur. On crawler cranes tipping occurs when any crawler roller is lifted 2 inches away from those treads remaining on the supporting surface. Tipping occurs on wheel or truck mounted carriers when all tires on one or more wheels leave the supporting surface.

g. Condition of the Crane. The maximum safe lifting capacity of cranes is usually available only when the equipment is relatively new. As the crane is used or becomes older, its condition can deteriorate so that it can no longer perform certain jobs safely. The following items should have adequate checks to assure that their condition will not limit lifting capacities: type, size and condition of wire ropes; type, size and condition of hookblock; structural condition of the boom; mechanical condition of the engine; and the adjustments and functional qualities of the clutches and brakes. Figure 2–7 and table 2–3 give working range dimensions and maximum allowable lifting loads, respectively, for a typical 10-ton crawler crane. The following example problem of crane capacity determination is based on figure 2–7 and table 2–3.

Problem: On a jobsite there are two loads tha must be lifted; Load A and Load B. Load A weights 4 tons and must be lifted high enough to allow 25 feet clearance underneath. Load A is in such a position that the operating radius for the crane will be 20 feet. Load B weights 3 tons and must be lifted high enough to allow 15 feet clearance underneath. Operating radius for the crane will be 30 feet when lifting Load B. Using a 10-ton hook block rigged for 3-part hoist line and allowing 10 feet of clearance under the boom point sheave for the load and slings, will the 10 ton crawler crane be sufficient for the job?

Solution:

Load A: By refering to fig. 2–7 it can be

Table 2-3. Maximum Allowable Lifting Loads for 10-Ton Crawler Crane

Length of boom (ft)	Operating radius (ft)	Equivalent angle of boom approx degrees	Height of boom point sheave pin above ground (ft)	Crane service 75% of tipping loads. Machine on firm level ground Ctwt. A (lbs)	Ctwt B (lbs)
	12	76	38.5	17500	19700
	15	71	37.5	12650	14250
	17.5	66	36.5	10250	11500
	20	62	35.25	8500	9600
35	22.5	51	33.75	7300	8250
	25	52	32.0	6300	7200
	27.5	47	30.0	5550	6350
	30	41	27.25	4950	5700
	32.5	34	24.0	4450	5100
	12	78	43.5	17450	19650
	15	73	42.75	12600	14200
	20	66	41.0	8450	9600
40	25	57	38.25	6250	7150
	30	48	34.25	4900	5650
	35	32	29.0	4000	4600
	37.5	32	25.5	3600	4200
	15	75	48.0	12550	14100
	20	68	46.25	8400	9500
	25	61	44.0	6200	7050
45	30	54	39.5	4850	5550
	35	45	36.5	3950	4550
	40	36	30.75	3250	3800
	15	77	53.0	12450	14050
	20	71	51.75	8300	9450
	25	64	49.5	6100	7000
50	30	58	46.75	4750	5500
	35	51	43.25	3850	4450
	40	43	38.5	3150	3700
	45	34	32.25	2650	3150

HOOK BLOCKS

Deduct weight of hook and slings from tabulated loads.

10-ton—single sheave, swivel hook block, block can be rigged 2-or 3-part.

(Standard Equipment) .... 250 lbs.

seen that the 10 ton hook block rigged for a 3-part hoist line requires 5 feet of clearance under the boom tip sheave pin. This 5 feet added to the 10 feet required for load and slings plus the required 25 feet under the load gives a total of 40 feet clearance necessary under the boom tip. Entering the bottom of figure 2-7 with an operating radius of 20 feet and reading up to a height above ground of 40 feet it can be seen that the minimum boom length required is 40 feet. Table 2-3 shows that with a 40 foot boom and 20 foot operating radius the maximum allowable lifting load will be either 8,450 pounds or 9,600 pounds, depending on the counterweight used. Deducting the weight of the hook block (250 lbs) the maximum allowable loads become 8,200 pounds and 9,350 pounds, respectively.

Load B: Allowing 5 feet of clearance for the hook block, 10 feet for the sling and load, and 15 feet required under the load, the minimum clearance necessary under the boom point is 30 feet. Figure 2–7 shows that with an operating radius of 30 feet and a clearance of 30 feet beneath the tip, the minimum length boom necessary is 40 feet. In table 2–3 it can be seen that the maximum allowable lifting loads for a 40 foot boom and 30 foot operating radius are 4,900 pounds and 5,650 pounds, again depending on the counterweight used. These values are reduced by the weight of the hook block (250 lbs) and become 4,650 pounds and 5,400 pounds, respectively.

Conclusion: It can be seen from the above that the 10 ton crawler crane will be able to lift load A (4 tons) but due primarily to the increased operating radius will not be able to lift load B (3 tons). If the crane cannot be moved closer (to reduce the operating radius) a larger capacity crane should be sent to the job site.

2–10. Tips for Efficient Crane Operation

a. Be sure the footing is adequate.

b. Where repetitive lifting is involved, the crane should be positioned for the shortest possible swing.

c. Level footing to avoid swinging "uphill" or "downhill". This reduces power requirement and increases speed and safety.

d. Use taglines on bulky loads to avoid excessive swinging of load.

e. Use adequate lengths of hoist line to assure full travel of the block to the lowest point required.

f. Organize the work for minimum travel time. As far as possible, lifts needed in one area should be completed before moving to a new location.

g. Use power-down device on equipment if available where precise load handling is required.

h. Do not use excessive counterweight or tie-down devices to increase stability. Their use will cause excessive stress and equipment failures.

Section III. CLAMSHELLS

2–11. Clamshell Description

Clamshell equipment consists of a crane boom, hoist drum laggings, clamshell bucket, tagline, and the necessary wire ropes—boom, holding, closing, and tagline. The boom is the same as that used with the crane and can be lengthened only by the use of boom center sections. The connections will be fitted together by any one of the two methods discussed with the crane. The drum laggings used on the clamshell may be the same as those used for the crane or may be changed to meet the speed and pull required for effective operation. This requirement changes with the design of the item of equipment, and the technical manual on the machine should be checked. The same wire ropes that are used during the crane operation can, for the most part, be used for clamshell operations. However, two additional lines must be added. These are the secondary hoist line and the tagline. The tagline winder is a device used to control the tension on the tagline to prevent the clamshell bucket from twisting during operation. Some older machines use various devices such as a heavy weight which slides or rolls up and down the boom. Newer machines use the spring loaded automatic reel type. This type of tagline winder, like the clamshell bucket, is interchangeable with any make or model in the same size range. The clamshell bucket consists of two scoops hinged together. Counterweights are bolted around the hinge. The bucket is controlled by the holding, closing, and tag lines. At the start of the digging cycle the bucket rests on the material with the

shells open. As the closing line wire rope is wound up on the drum lagging, the shells are drawn together causing them to dig into the material. The weight of the bucket, which is the only crowding action available, helps the bucket to penetrate the material. The bucket is then raised by the holding and closing lines and swung to the dumping point where the bucket is opened by releasing the tension on the closing line.

2-12. Clamshell Characteristics and Capabilities

Like the crane, the clamshell is a vertically operated attachment capable of working at, above, and below ground level, but equipped with a bucket instead of a hook block. The clamshell is capable of digging loose to medium type soils in all zones as well as dumping in any of the three zones. The height that can be reached by the clamshell is dependent on the length of boom used. The depth reached by the clamshell is limited by the length of wire rope that the cable drums will accomodate. The weight that a clamshell can handle is dependent on the lifting capacity factors. The basic problem here is that the weight the clam andles is quite variable. To obtain the safe fting capacity for the clamshell, refer to the ppropriate crane capacity table (found in he operator's manual) for the boom length and operating radius, then multiply the allowable load listed by 0.88. This reduces the allowable load to two thirds of the tipping load for an additional safety factor.

2-13. Clamshell Employment

The jobs on which the clamshell can be used are numerous. However, it is considered the best for such jobs as excavating vertical shafts or footings, filling aggregate bins or hoppers, and unloading aggregate from flat bottom railroad gondola cars.

a. Loading Aggregate Bins. When loading aggregate bins or hoppers, the clamshell should be positioned to avoid excessive raising and lowering of the boom or movement of the machine between the aggregate stockpiles and the hoppers. If two clamshells are to be used, each should be positioned where it can load from one stockpile and dump into the hopper. The use of two clamshells to keep one hopper filled is not a good practice. Careful timing by the operators is required to avoid contact with each other when swinging the booms toward the hopper.

b. Shaft or Footing Excavation. Since the dimensions of this type of excavation may vary it would be difficult to discuss the position of the clamshell relative to digging efficiently. Two important facts which must always be considered are the amount of wire rope on the machine, and the need for the outside edge of the cut to be kept lower than the center, which keeps the bucket from drifting toward the center and thus causing a V-shaped excavation. In deep excavation it is generally necessary to have a bucket spotter or signalman to guide the operator. This is especially true when the bucket is out of the operator's sight. It may also be necessary to use hand taglines to guide the bucket.

c. Unloading Gondola Cars. The clamshell should be positioned parallel to the cars if possible. Starting at one end and digging on the sides enables the work to progress either by moving the machine or by moving the car. The procedure is similar to that used in unloading barges.

2-14. Production Rates for Clamshells

Because of the variable factors which affect the operation of clamshells, it is difficult to arrive at production rates that are dependable. These factors include the difficulty of loading the bucket in different types of soils, the height of lift, the slow swing required, and the method of disposing of the load. For example, if the material is loaded into a truck, the time required to spot the bucket over the truck and dump is greater than when the material is dumped onto a spoil pile. The best method for production estimation is to observe the equipment on the job and measure the cycle time. The amount of material to be moved divided by material moved per cycle times number of cycles per hour times an efficiency

factor results in a good estimate in hours to complete the job. Thus:

$$\text{Time} = \frac{\text{Production Required}}{\text{Production Rate}}$$

Production Rate =
material moved per cycle

$$\frac{\text{(cubic yards (sec/hr worked) (efficiecy factor)}}{\text{time in sec/hr for one cycle}}$$

Estimates can be made without the efficiency factor (table 2-4) but would only reflect an estimate based on the seconds worked per hour, and optimum production.

Example: 450 cubic yards of aggregate will be loaded into haul units from a stockpile by a ¾ cu yd clamshell. The average cycle time was determined to be 40 seconds. The job factor is rated as fair. The management factor is rated as good. Determine the number of hours required to do the job, based on a 50-minute hour.

Solution.

$$\text{Production Rate} = \frac{\text{(.75 cu yds) (3000 sec/hr) (eff. factor .69)}}{\text{Average cycle time 40 seconds}}$$

$$= 38.8 \text{ cu yds/hr}$$

$$\text{Time (hours)} = \frac{\text{Production Required (cu yds)}}{\text{Production Rate (cu yds/hr)}}$$

$$= \frac{\text{450 cu yds Production}}{\text{38.8 production rate}} =$$

11.6 hours or approximately 12 hours.

Table 2-4. Typical Efficiency Factors for Lift-Loading Equipment

Job factors [1]	Management factors [2]			
	1. Excellent	2. Good	3. Fair	4. Poor
1 Excellent	.84	.81	.76	.70
2 Good	.78	.75	.71	.65
3 Fair	.72	.69	.65	.60
4 Poor	.63	.61	.57	.52

[1] JOB FACTORS—Job factors are the physical conditions pertaining to a specific job which affect the production rate, other than the class of material to be handled. These include: (1) Topography and the work dimensions which include the depth of cut and whether the work will require a great deal of movement; (2) Surface and weather conditions which include the seasons and the question of drainage; (3) Specification requirements which control the manner in which the work must be handled or indicate the operational sequence.

[2] MANAGEMENT FACTORS—These include: (1) Selection, training and direction of men; (2) Selection, care, and repair of equipment; (3) Planning, job layout, and supervising and coordinating the operations.

2-15. Tips for Efficient Clamshell Operation

a. Level ground is preferred for positioning the unit to avoid swinging "uphill or downhill"—a power consuming, time wasting condition where repetitive handling is involved.

b. Position the unit so that the clamming or digging operation is at the same radius as the dumping operation to avoid excessive wear on the boom mechanism and the wasting of production time by raising and lowering the boom.

c. Select the correct size of bucket for the machine. The efficient use of the clamshell means an efficient cycle of digging, hoisting, swinging, and dumping. Large buckets may increase cycle time.

Section IV. PILEDRIVERS

2-16. General

The piledriver attachment consists of a crane boom, adapter plates, leads, catwalk, hammer, pile cap and the necessary wire ropes. The adapter plates are bolted to the top section of the leads and are fastened to the boom tip shaft. The leads are fastened to the foot of the boom by the telescopic braces that make up the catwalk. The hammer may be air, steam, diesel, or gravity operated. The piledriver is used to drive various types of wood, steel and concrete piling for foundations, bridge bents, piers and wharves.

2-17. Air and Steam Hammers

Air or steam hammers may be available in some situations although they are no longer standard engineer equipment. The capacities of these hammers are 4,150 and 8,750 foot-pounds. Each hammer consists of a stationary cylinder and a moving ram which includes a piston and striking head. The piston is raised

by compressed air or steam pressure. The driving force is secured from the downward pressure applied to the piston and its gravity fall. The 4,150 foot-pound air or steam hammer is especially useful when used as a pile extractor.

2-18. Diesel Hammers

Diesel-driven, self-powered, piledriving hammers of 8,000 to 22,400 foot-pound ratings are now standard engineer equipment. These are made in two types—the open-top and the closed-end hammers. Both types are self-contained, free-piston engines, operating on a two cycles, compression-ignition principle. The diesel-driven hammers eliminate the need for an air compressor or steam boiler. These hammers, however, cannot be used to pull piles. They are suitable for use with the military truck and crawler piledrivers, and can be used to drive various types of wood, steel and concrete piling for foundations, bridge bents piers and wharves. If the piling is being driven in very soft soil, difficulty may be experienced with the hammer firing once but failing to continue. This is due to all the energy from the fuel ignition being absorbed in the pile and the ground, with an insufficient amount to re-cycle the hammer being reflected upward. When this condition occurs, it is best to revert to the use of the drophammer to drive the pile until sufficient driving resistance for efficient diesel-hammer operation is reached.

2-19. Drophammers

The drophammer piledriving equipment is best used for driving vertical piling because part of the driving force is lost in friction with the pile leads whenever they are angled from the vertical. The drophammer driving action is relatively slow in comparison with other types of hammers. For efficient driving the weight of the hammer must be equal to the weight of the pile being driven, although a hammer weight twice that of the pile will give best results. For best results the drop hammer is raised only about 10 feet when driving, and the raising and dropping of the hammer should be kept at a steady rate of speed Raising of the hammer to the top of the leads each time will considerably slow down the driving action.

2-20. Piledriver Employment

The piledriver should be placed so the minimum amount of time is lost due to moving This placement is generally parallel to the long axis of the pile group. The piles then should be close enough to the site that the operator need only swing to pick up the next pile. The piledriver should be placed on level stable soil while driving. When driving piles from a barge, the barge should be anchored tightly and remain stationary. Piles are preferably driven off the end of the barge. Light continuous blows by the pile hammer are perferred rather than heavy infrequent blows The latter causes more pile failures. Further information on piledriving and on piling materials and design may be obtained from Technical Manual 5-258, Pile Construction.

Section V. DRAGLINES

2-21. Dragline Components

The dragline components consists of the lattice type boom, dragline bucket, and fairlead assembly. The wire ropes that are used are the boom suspension, drag, bucket hoist, and dump. The fair-lead accomplishes what its name implies—it guides the cable onto the drum during loading operation of the bucket. The hoist rope, which operates over the boom point sheave, is used to raise and lower the bucket. The drag rope is used to pull the bucket through the material in the digging operation. When the bucket has been raised and moved to the dump point, it is emptied by releasing the tension on the drag rope. Dragline buckets are rated in different types and classes for all size buckets. The types of buckets are Type 1 (light duty), Type II (medium duty), and Type III (heavy duty). The classes of buckets are Class P (perforated plate), and Class S (solid plate). Type II, Class S buckets are most generally procured for military use

The Class P bucket can be procured from Class IV supply depots by the using unit for use on dredging operations.

2-22. Dragline Characteristics

The dragline is a very versatile machine which is capable of a wide range of operations at and below ground level. The type of material which can be handled ranges from soft to medium hard. The greatest advantage of a dragline over other machines is its long reach for both digging and dumping. Another advantage is its high cycle speed, being second only to the shovel in this regard. The dragline does not have the positive digging force of the shovel or backhoe since the bucket is not weighted or held in alignment by rigid structures. Therefore, it can bounce, tip over or drift sideward when it encounters hard material. These weaknesses increase with digging depth and are particularly noticeable with the smaller machines. The dragline's operating radius is increased by the throw or casting of the bucket, which can be up to ⅓ to ½ the dumping height (fig. 2-8). Two casting methods may be used: the frontal cast and the side cast. The frontal cast is accomplished by raising the bucket midway between the ground and boom tip, taking in on the dragline causing the bucket to be pulled under the boom. Then, when the drag cable brake is released the weight of the bucket pulls the drag cable off the drum and the bucket will swing out beyond the boom tip, at which time it is lowered to the ground in the digging position. The side cast is accomplished by using the swing of the superstructure to cast the bucket beyond the tip of the boom, at which time it is lowered to the ground in the digging position. When the bucket is cast beyond the tip of the boom, some control of the bucket is lost. The dragline, not being a rigid attachment, will not dump its material as accurately as other excavators. When a load is dumped into a haul unit or hopper, more time is required for positioning of the bucket prior to dumping it.

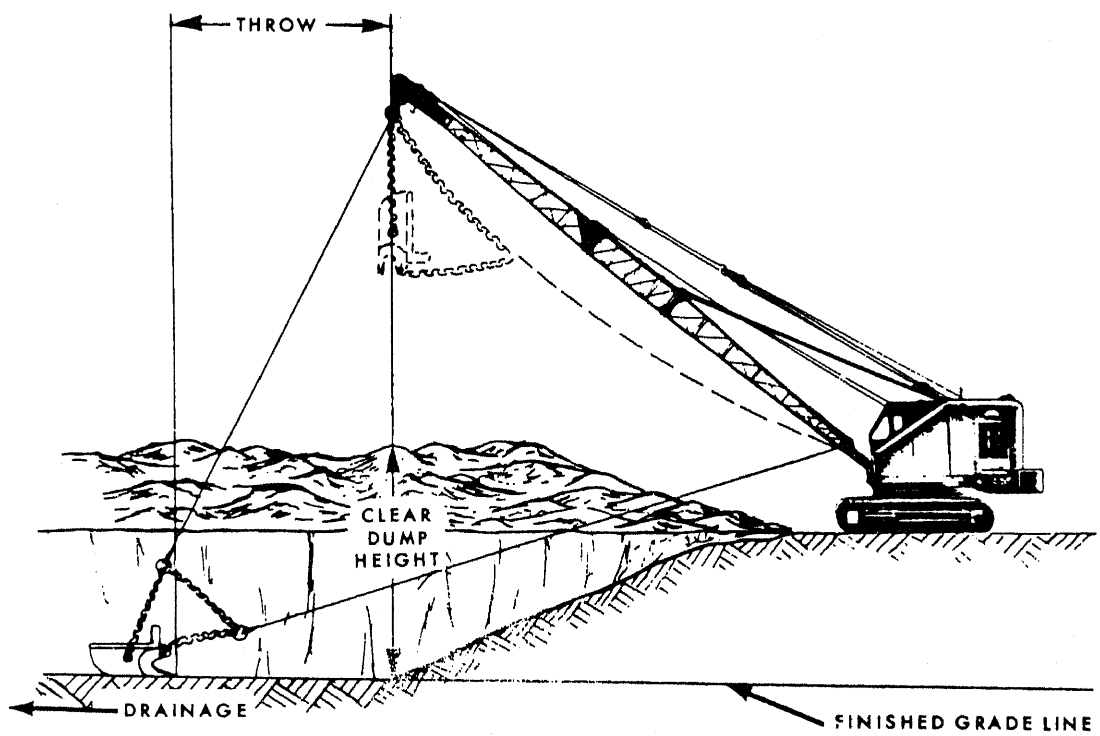


Figure 2-8. Dragline throw.

2-23. Factors Affecting Dragline Capacity

The boom of the dragline may be set at a relatively low angle for operation, but boom angles of less than 35° from the horizontal are seldom advisable for dragline work due to the possibility of tipping the machine. When excavating wet sticky material with the dragline and cast dumping it onto a spoil bank, the chance of tipping the machine is increased because the material tends to hang in the bucket, increasing the moment at the end of the boom. When working a crawler dragline, the heavy counterweight must be used. Without it the capacity of the machine will be reduced due to a tipping tendency.

2-24. Dragline Employment

There are many tasks the dragline can effectively accomplish. It can be employed on dredging operations where the material handled is wet and sticky. It can dig trenches, strip overburden, clean and dig roadside ditches, and slope embankments. When handling mud the dragline is the most practical attachment to use as its reach enables it to handle a wide area from one position, and the sliding action of the bucket avoids trouble with suction.

a. In-Line Approach. When excavating a rench with the dragline the machine should ›e centered on the excavation, and the rawlers or carrier should be in line with it ‹fig. 2-9). The dragline cuts or digs to the front and dumps on either side of the excavation. The machine moves away from the face as the work progresses.

b. Parallel Approach. The dragline can slope an embankment more effectively by working it from the bottom to the top. The machine is positioned on the top with the crawlers parallel to the working face which enables it to move the full length of the job without excessive turning (fig. 2-10).

c. Drainage. A dragline is ideal if earth has to be removed from a trench, canal, gravel pit, or the like, containing water. However, drainage ditches may be required to carry away water from the construction site, or the work can be planned to begin at the lowest grade point on the job so that drainage will be provided as the dragline progresses toward higher levels. Draglines can and do work with their crawlers under water but this necessitates slow moves and involves treacherous footing. Digging under water or in wet materials increases the weight of materials and frequently prevent carrying heaped bucket loads. The operation should be planned to work as dry as possible and to provide drainage for existing water as well as rains which might otherwise slow down or delay production. Drainage projects involving ditch excavation through swamps or soft terrain are common applications. Normally under these conditions the excavated material is cast onto a levee or spoil bank which eliminates the problem of constructing roads for hauling equipment. However, it may be necessary to construct some sort of rudimentary supply and service road.

d. Loading Haul Units. Where job conditions require the excavated material to be loaded into hauling units, the excavation should be opened up in such a manner that the loaded hauling equipment can travel on high, dry ground or on the advantageous grades. The spotting of trucks and dragline should be planned for minimum boom swing with the truck bed under the boom point and the long axis of the bed parallel with the long axis of the boom or at right angles to the boom. More spillage is to be expected from dragline than from shovel loading. The dragline operator has no rigid control of the bucket. Even a skilled operator has a hard time positioning every pass over the center of his target.

2-25. Dragline Production Estimation

Hourly production rates for draglines are given in table 2-5. These rates are based on optimum cutting depth, 90° swing angle volume of soil in the bank (in place) condition, and maximum efficiency. Table 2-6 gives correction factors for different cutting depths and swing angles. Table 2-7 gives soil conversion factors. Overall efficiency should be determined from past experience. If past efficiency factors are not available table 2-4 may be used as a guide.

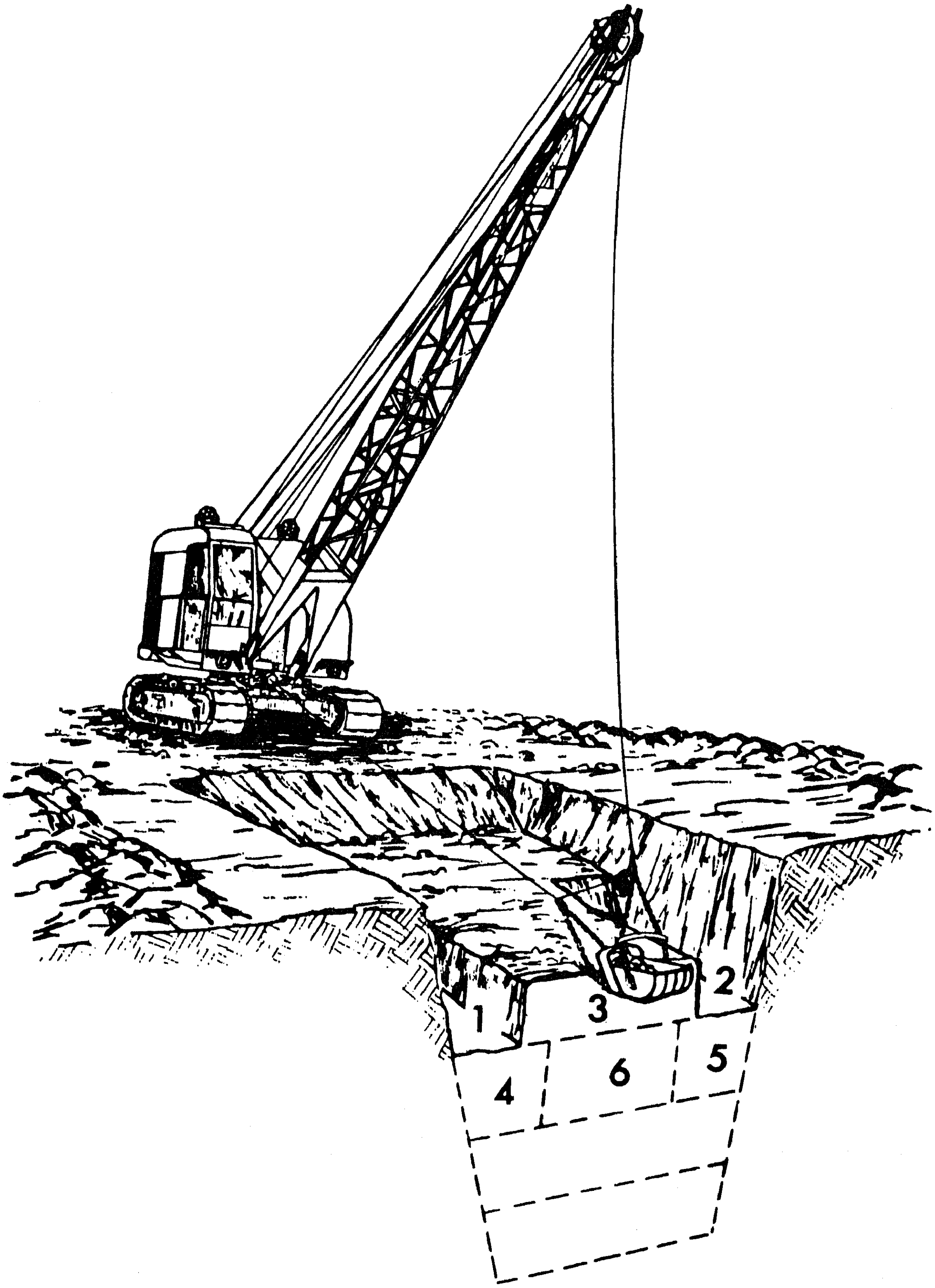


Figure 2-9. In-line approach with dragline.

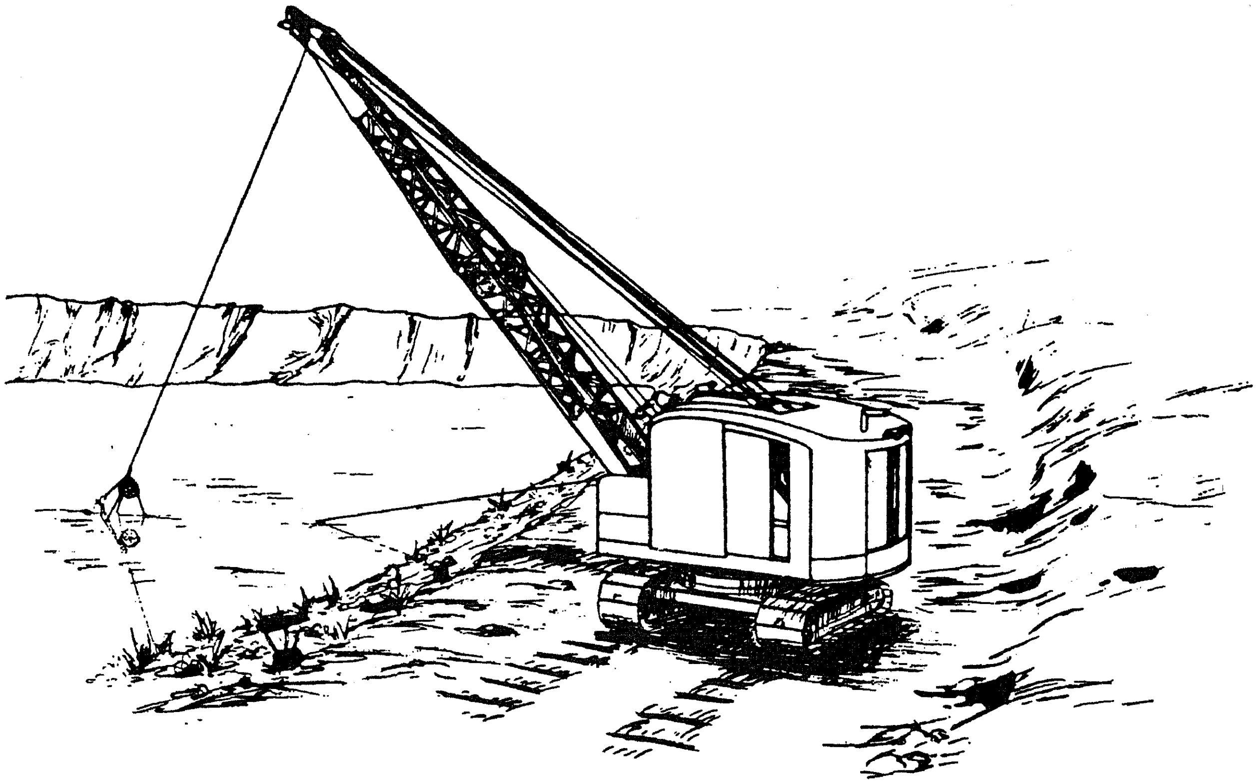


Figure 2-10. Parallel approach with dragline.

Table 2-5. Hourly Short Boom Dragline Output in Cubic Yards.

Class of Material	Dragline Bucket Size (cu yds) ⅜	½	¾	1	1¼	1½	1¾	2	2½
Light, Moist Clay	5.0	5.5	6.0	6.6	7.0	7.4	7.7	8.0	8.5
or Loam	70	95	130	160	195	220	245	265	305
Sand or Gravel	5.0	5.5	6.0	6.6	7.0	7.4	7.7	8.0	8.5
	65	90	125	155	185	210	235	255	295
Good Common Earth	6.0	6.7	7.4	8.0	8.5	9.0	9.5	9.9	10.5
	55	75	105	135	165	190	210	230	265
Clay; Hard, Tough	7.3	8.0	8.7	9.3	10.0	10.7	11.3	11.8	12.3
	35	55	90	110	135	160	180	195	230
Clay; Wet, Sticky	7.3	8.0	8.7	9.3	10.0	10.7	11.3	11.8	12.3
	20	30	55	75	95	110	130	145	175

Note. Top figure denotes optimum depth of cut in feet and inches—Bottom figure denotes cubic yards per hour (in place)

Table 2-6. Dragline Conversion Factors for Depth and Swing Angle.

Depth of cut in percent of optimum	Angle of swing in degrees							
	30	45	60	75	90	120	150	180
20	1.06	.99	.94	.90	.87	.81	.75	.70
40	1.17	1.08	1.02	.97	.93	.85	.78	.72
60	1.24	1.13	1.06	1.01	.97	.88	.80	.74
80	1.29	1.17	1.09	1.04	.99	.90	.82	.76
100	1.32	1.19	1.11	1.05	1.00	.91	.83	.77
120	1.29	1.17	1.09	1.03	.985	.90	.82	.76
140	1.25	1.14	1.06	1.00	.96	.88	.81	.75
160	1.20	1.10	1.02	.97	.93	.85	.79	.73
180	1.15	1.05	.98	.94	.90	.82	.76	.71
200	1.10	1.00	.94	.90	.87	.79	.73	.69

Table 2-7. Soil Conversion Factors.
(Conversion factors for earth-volume change)

Soil type	Soil condition initially	Converted to		
		Bank (In Place)	Loose	Compacted
Sand	Bank (In Place)	----	1.11	0.95
	Loose	.90	----	.86
	Compacted	1.05	1.17	----
Loam	Bank (In Place)	----	1.25	0.90
	Loose	.80	----	.72
	Compacted	1.11	1.39	----
Clay	Bank (In Place)	----	1.43	0.90
	Loose	.70	----	.63
	Compacted	1.11	1.59	----
Rock (blasted)	Bank (In Place)	--	1.50	1.30
	Loose	.67	----	.87
	Compacted	.77	1.15	----
Coral comparable to limestone	Bank (In Place)	----	1.50	1.30
	Loose	.67	----	.87
	Compacted	.77	1.15	----

Example:

Determine the corrected hourly output for a ¾ cubic yard crawler mounted dragline.

Given: Bucket size—¾ cu. yd.
Material—good common earth
Angle of swing—45°
Depth of cut—9 ft.
Job factor—good
Management factor—good

Step 1. Select the estimated production from table 2-5. (105 cu. yd. @ 7.4 ft.)

Step 2. Determine the percent of optimum depth of cut. ($\frac{9}{7.4} = 121.7\%$; say 120%)

Step 3. Determine the correction factor from table 2-6, using the determined percent of optimum depth of cut and angle of swing. (1.17)

Step 4. Determine overall efficiency factor from table 2-4. (.75)

Step 5. Multiply the estimated production by the correction factor by the efficiency factor = probable production 105 x 1.17 x .75 = 92.1 cu. yd. per hour, bank measure *.

2-26. Tips for Efficient Dragline Operation

a. Although the dragline bucket can be readily cast beyond the length of the boom, the

* To convert to either loose or compacted yardage, use table 2-7.

machine should be positioned to eliminate unnecessary casting and hoisting.

b. Use heavy timber mats for work on soft ground. The mats should be kept level and clean if possible.

c. When positioning a dragline on a job, access for maintenance, operating personnel, and hauling equipment should be assured.

d. The working area should be excavated in layers, not in trenches, and kept sloped upward toward the machine.

e. The bucket should not be dragged in s close to the machine that it will build up pil and ridges of material in front of the machin

f. Used pieces of hoist and drag rope ma be salvaged for use as the dump rope.

g. The bucket should never be guided b swinging the superstructure while diggin This puts side stress on the boom which ca cause failure. The swing should not be start until the bucket has been raised clear of tl ground.

Section VI. BACKHOES

2-27. Introduction

The backhoe attachment consists of five major components: dipper, dipper handle, box type boom, auxiliary A-frame, and a grooved drum lagging that is installed on the front drum for the dipper pull rope. Used with these components are dipper pitch braces, dipper padlock, sheave, dipper teeth and side plates, dipper hinge pin, dipper hoist sheave, boom foot pins and wire rope for A-frame suspension boom hoist, and dipper pull rope. Like other types of crane-shovel equipment, it is necessary first to determine the most efficient backhoe size and mounting. Having accomplished this, it is important that the machine be properly set up on the job to gain its greatest effectiveness. If the job is to continue during the wet seasons and in wet areas, drainage must be given prime consideration. Since the backhoe is used primarily for below-track-level excavations, a survey for underground hazards as well as surface obstacles should be conducted prior to commencement of operation. This is particularly true in populated areas where utilities are underground. Working in confined quarters is not efficient from a production standpoint. If considerable closequarter work is expected it is advisable to use small machines which can operate efficiently within a minimum work radius. The use of hand labor may be necessary when excavating near underground utilities.

2-28. Backhoe Characteristics

The backhoe is most suited for trench excavating as it is capable or digging well belo the tracks of the unit, and capable also digging soft to hard material because tl weight of the boom plus the positive pull the dipper is used to force the dipper into tl material. The backhoe combines the featur of the shovel and the dragline. Its dipper similar to the shovel dipper but it digs towa the machine like a dragline bucket instead away from it like the shovel. The backh uses a heavy steel boom similar to the shov boom. The dipper is mounted on the end of heavy steel arm called the dipper handle whi pivots on the end of the boom. At the heel of tl boom there is a jib frame or mast whi supports several sheaves. This mast is su ported and controlled by a cable running fro the boom hoist drum. The backhoe boom raised and lowered by a cable operating fro the main hoist drum. The dipper is crowd in by a drag cable operating from the fro drum.

2-29. Backhoe Employment

The efficient positioning of the backhoe is co tingent on the type of work to be done a may vary between jobs. The backhoe is nc mally associated with two types of excav tions, trenching and basement.

a. Trenching. When excavating a tren with the backhoe the machine should be ce tered on the trench and the crawler or carri in line with it. As the digging progresses t machine is moved away from the end of t excavation and the material is disposed of

loading in haul units or stockpiling along the side of the trench for back fill. Another method which can be used involves digging trenches in two cuts or lifts (figure 2–11). Make the first cut (with boom carried high) to excavate the top 35 to 45 percent of the trench depth. Then move forward about ½ the length of the machine and remove the remainder of the material with the boom carried low to facilitate finishing the trench cut. This method, although involving more and shorter moves of the machine, has its advantages in better digging angles of the dipper, better filling of the dipper, and shorter hoisting distance on top lifts. This method also affords the operator better visibility because of close in dipper action. However, one great disadvantage to being so close to the cut is that the machine may fall into the trench if the bank should cave in.

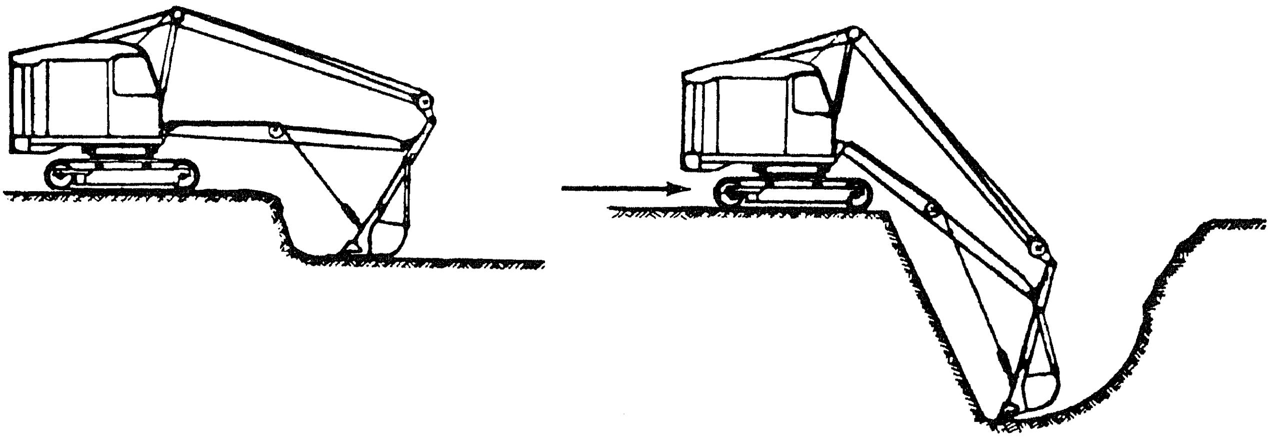


Figure 2–11. Digging with the backhoe.

b. Basement Type Excavations. For basement type excavations the procedures vary according to the shape of the basement being excavated, the restrictions of surrounding properties or buildings, and the requirements for disposing of the spoil. Trenches for service pipes should be dug last. This is accomplished by digging from the basement outward. When using the backhoe for basement type excavation, the starting point and digging sequence should be planned so that the machine conveniently works itself out, free of the job. Many variations of the two operating plans shown in figure 2–12 are possible. The machine straddles the outer edge and digging is done over the end and side of the carrier. The machine moves as the arrows indicate.

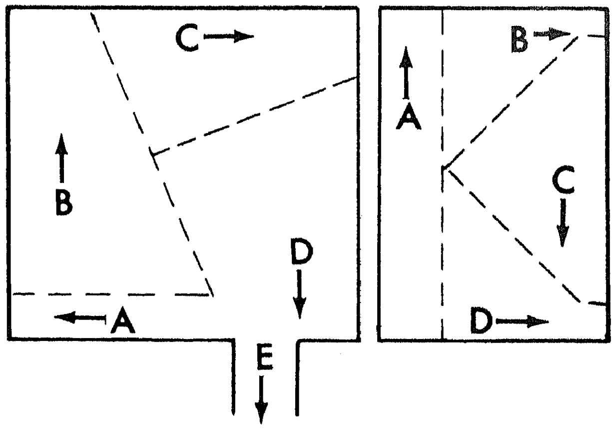


Figure 2–12. Two methods of excavating basements using backhoe.

c. Loading Trucks. The backhoe is used for truck loading in some instances. However, when loading trucks, the backhoe is sloppy and somewhat inefficient and has a slow digging cycle. The sloppiness is due to material falling off the teeth as the bucket is lifted toward the dumping position and the inefficiency results from the maneuvering necessary to complete a dump within the length of a truck body. The slow cycle is caused by the

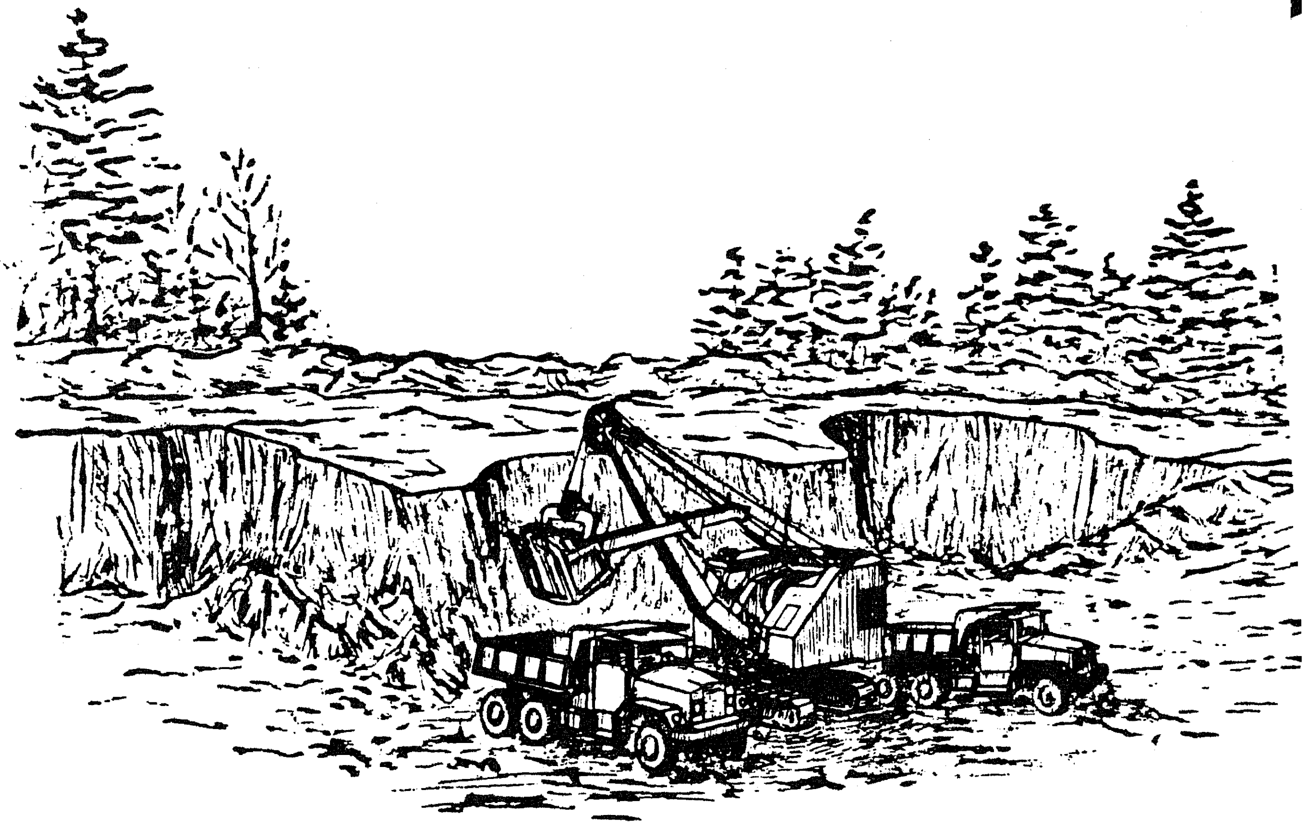


Figure 2-14. Frontal approach with shovel.

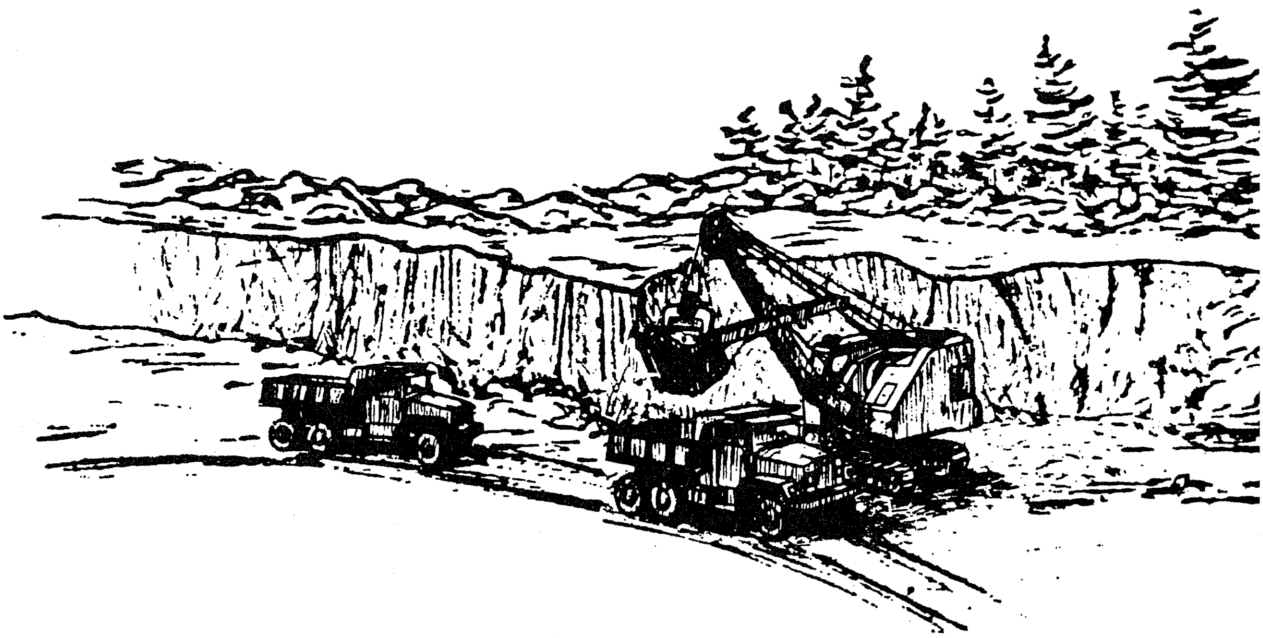


Figure 2-15. Parallel approach with shovel.

he optimum depth of cut, such as a high hill ›r deep pit, best results will be obtained by aking out the cut in multiple lifts or benches, he depth of each approximating the optimum :utting depth.

a. Side Hill Operations. In this procedure, :he shovel starts on the upper portion of the ıill and takes out a lift at approximately the ›ptimum depth of cut for that material and .n a width equal to the face that may be cov- ›red efficiently with the parallel approach method of operation. At the end of the first pass, the shovel turns around and takes out an adjoining lift. Then the shovel is moved downhill to the next level and takes out additional sections in the same manner as required to complete the excavation (fig. 2-16). As the excavation becomes larger, the benches should be widened to permit a frontal approach for more efficient loading of haul units.

b. Subsurface Operations. It is sometimes necessary to excavate material from deposits below the ground in level terrain. This type of pit is particularly adaptable to gravel deposits where drainage is not a problem. Where deposits are sufficiently large, pits are best developed by the circular bench method figure 2-17. The procedure is to start the shovel digging on a down grade of not over 10 percent until it is working against a bank of suitable height. Until the initial cut is advanced to a height of six feet, trucks are kept on the surface or ramp for loading. When the initial cut is completed, the shovel widens the pit by making additional cuts. Trucks are then spotted in the first cut for loading while the shovel is making the second cut. As the pit is enlarged from successive cuts, it assumes a circular shape and the benches may be widened to permit spotting of haul units on a level with the shovel. Development of succeeding levels is the same as for the first.

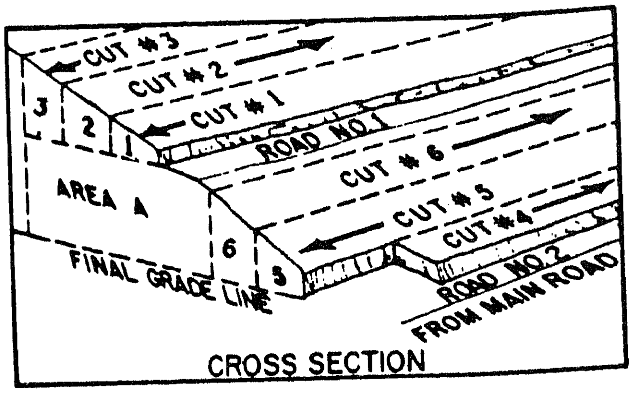


Figure 2-16. Side hill cut, benching method.

2-36. Production Estimation

The working range of the shovel varies with the type of mounting and size of shovel being used. Within these working ranges, the out-

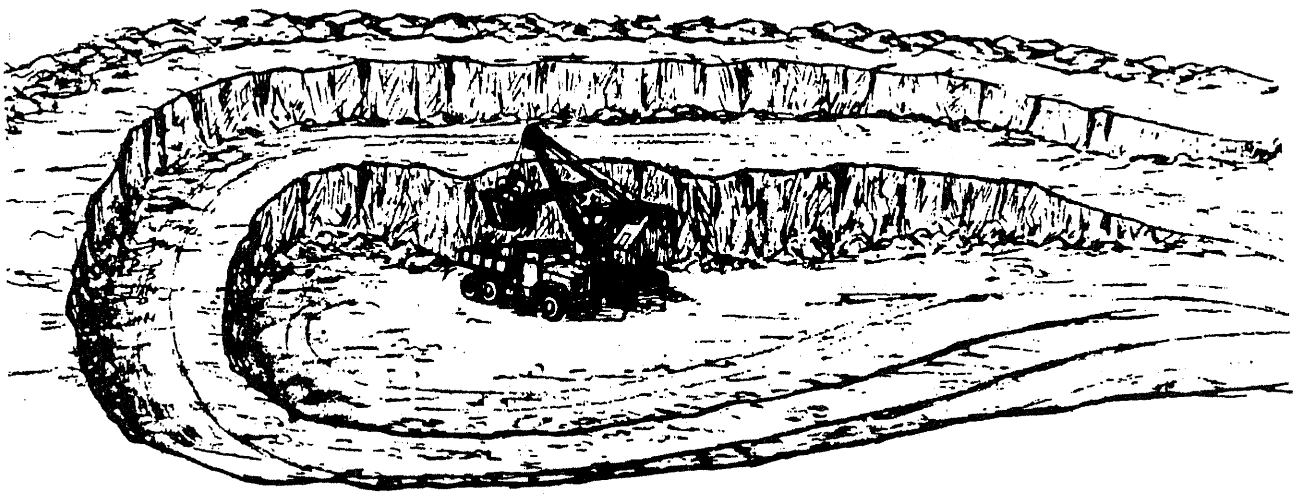


Figure 2-17. Sub-surface circular pit.

puts of the shovels vary widely. The rate at which the bucket fills depends on the nature of the material. The output per hour also depends greatly on the depth of cut (height of bank) and the degree of swing. Table 2-8 shows the estimated shovel hourly output based on the different types of materials (using an optimum depth of cut to allow filling the bucket without undue crowding and hoisting), a swing angle of 90° and the loading of "properly sized" haul units. Changing any of the figures on which this table is based wi increase or decrease the hourly output capa bilities of a particular size shovel. Table 2- gives conversion factors for different swin angles and depths of cut for crane shovel o eration and efficiency factors are given i table 2-4. The procedure for calculating d tailed output estimates for the shovel is e actly like that outlined for the dragline i paragraph 2-25.

Table 2-8. Hourly Shovel Output in Bank Cubic Yards.

Class of Material	Dipper Size (cu yds) 3/8	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/2
Moist Loam or	3.8	4.6	5.3	6.0	6.5	7.0	7.4	7.8	8.4
Light Sandy Clay	85	115	165	205	250	285	320	355	405
Sand and Gravel	3.8	4.6	5.3	6.0	6.5	7.0	7.4	7.8	8.4
	80	110	155	200	230	270	300	330	390
Good Common Earth	4.5	5.7	6.8	7.8	8.5	9.2	9.7	10.2	11.2
	70	95	135	175	210	240	270	300	350
Clay Hard Tough	6.0	7.0	8.0	9.0	9.8	10.7	11.5	12.2	13.3
	50	75	110	145	180	210	235	265	310
Rock Well Blasted	--	--	--	--	--	--	--	--	--
	40	60	95	125	155	180	205	230	275
Common, with	--	--	--	--	--	--	--	--	--
Rocks and Roots	30	50	80	105	130	155	180	200	245
Clay Wet and Sticky	6.0	7.0	8.0	9.0	9.8	10.7	11.5	12.2	13.3
	25	40	70	95	120	145	165	185	230
Rock, Poorly Blasted	--	--	--	--	--	--	--	--	--
	15	25	50	75	95	115	140	160	195

POWER SHOVEL YARDAGE—CONDITIONS: 1. Cu yds bank measurement per 60 min. hour with no delays
2. Suitable depth of cut for maximum effect.
3. All materials loaded into hauling units 90° swing

Note. Top figures denote optimum depth of cut in feet and inches—Bottom figures denote cubic yards per hour.

Table 2-9. Conversion Factors for Depth of Cut and Angle of Swing on Power Shovel Output

Depth of Cut In Percent of Optimum	Angle of Swing in Degrees 45	60	75	90	120	150	180
40	.93	.89	.85	.80	.72	.65	.59
60	1.10	1.03	.96	.91	.81	.73	.66
80	1.22	1.12	1.04	.98	.86	.77	.69
100	1.26	1.16	1.07	1.00	.88	.79	.71
120	1.20	1.11	1.03	.97	.86	.77	.70
140	1.12	1.04	.97	.91	.81	.73	.66
160	1.03	.96	.90	.85	.75	.67	.62

2-37. Techniques for Maximum Shovel Efficiency

a. The shovel should be worked as level as possible. When used in areas where material is soft, the shovel is supported on (fig. 2-3) construction mats. Only material that is broken up small enough to pass through the dipper should be handled.

b. At the start of digging the dipper should be at crawler (or wheel) level and 2 or 3 feet in front of the crawlers (or wheels).

c. Excavating too far beyond the boom point is never practical because the power available diminishes rapidly as the dipper stock is extended beyond the imaginary line plumbed from the boom point to the ground.

d. Proper spotting of the trucks plays an important part in increasing shovel production. They should be spotted on each side of the shovel (for frontal approach), but should not be spotted so close to the shovel that the counterweight will strike one of them during the swing of the superstructure. On the other hand they should not be spotted out so far that the shovel operator will have to overcrowd the dipper stick to reach them.

e. The shovel should travel on ground that is free of holes and large boulders in order that the tracks have bearing for their full length. A rocking shovel is difficult to operate and may cause damage to the track frames.

f. The shovel should be kept moved up to the working face. After each move up, the proper digging sequence is to start at the center of the face and make passes on each side of the center until all of the face within reach is cut back evenly. The dipper should be filled by a straight forward pass against a working face at optimum bank height. When the excavation is deep the working face is terraced.

g. When excavating hard material with the shovel, the practive of lifting hard enough to raise the tracks off the ground should be avoided because of possible damage to the track frames.

CHAPTER 3

SCOOP LOADERS AND FORKLIFTS

Section I. SCOOP LOADERS

3-1. Introduction

a. The scoop loader, sometimes referred to as a front-end loader or tractor-shovel, is a self-contained unit mounted on rubber tires or tracks (fig. 3-1), capable of controlling mounted attachments. The most common of the attachments are a bucket of traction shovel type and a forklift. The bucket is attached to the tractor by means of a push frame and lift arms and may be a conventional one piece type or the hinged jaw (multi-segment) type. When using the bucket, it is filled by moving the entire unit forward with bucket at the desired digging level. When filled, the bucket is tilted upward freeing the bucket load from the bank. The upward position is maintained while backing away to prevent spillage while being moved. Although scoop loaders are available in varied sizes and capacities, and include buckets up to 20 cubic yards, the military scoop loader generally falls in the 1½ to 2½ cubic yard range. The 1½ cubic yard loader is issued to airborne and air mobile units, and the 2½ cubic yard loader is issued to combat and construction units. They are diesel engine powered and are equipped with a transmission of the power-shift type providing four speed ratios forward and reverse. On older models of the 2½ cubic yard and smaller sizes, the front axle is rigid, with the rear axle providing the steering capabilities. On new models of the 2½ cubic yard size, the frame is hinged and the front axle provides the steering. This type is referred to as articulated. The hydraulic system provides the control necessary for operating the mounted attachments (fig. 3-2), and also assists in steering.

b. As illustrated in figure 3-2, the scoop loader may be equipped with different attachments. Scoop type shovels, referred to as buckets, are of two types—general purpose (1, fig. 3-1) and multi-segment (2, fig. 3-1).

(1) The general purpose or single piece bucket is constructed of heavy duty, all-welded steel, with bolts or welded replaceable cutting edges. Bolt-on type replaceable teeth are provided for excavation of medium type materials.

(2) The multi-segment bucket is constructed of heavy duty, all-welded steel, with bolted or welded replaceable cutting edges. Bolt-on type replaceable teeth are provided for excavation of medium type materials. The bucket is of two-piece type construction to provide capabilities not available in a single-piece bucket. Th multi-segment bucket (2, fig. 3-2) can be u ized as a clamshell, dozer, and scraper, as v as a scoop shovel. The forklift (3, fig. 3-2) . attached to the loader in place of a bucket o other attachment. The forklift attachable to the loader in place of a bucket is of steel construction with two moveable tines and is designed for use in material handling. Other attachments available, but in limited use in the military, are the crane hook designed for lifting and moving slung loads and the snow plow designed for the removal of snow from firm areas.

3-2. Scoop Loader Characteristics and Capabilities

a. *Rubber Tired Loaders*. Mounted on large rubber tires, the loader has a relatively low ground bearing pressure (45 pounds) that enables it to perform a large variety of jobs. The loader can attain speeds up to 29 miles per hour permitting good mobility from one

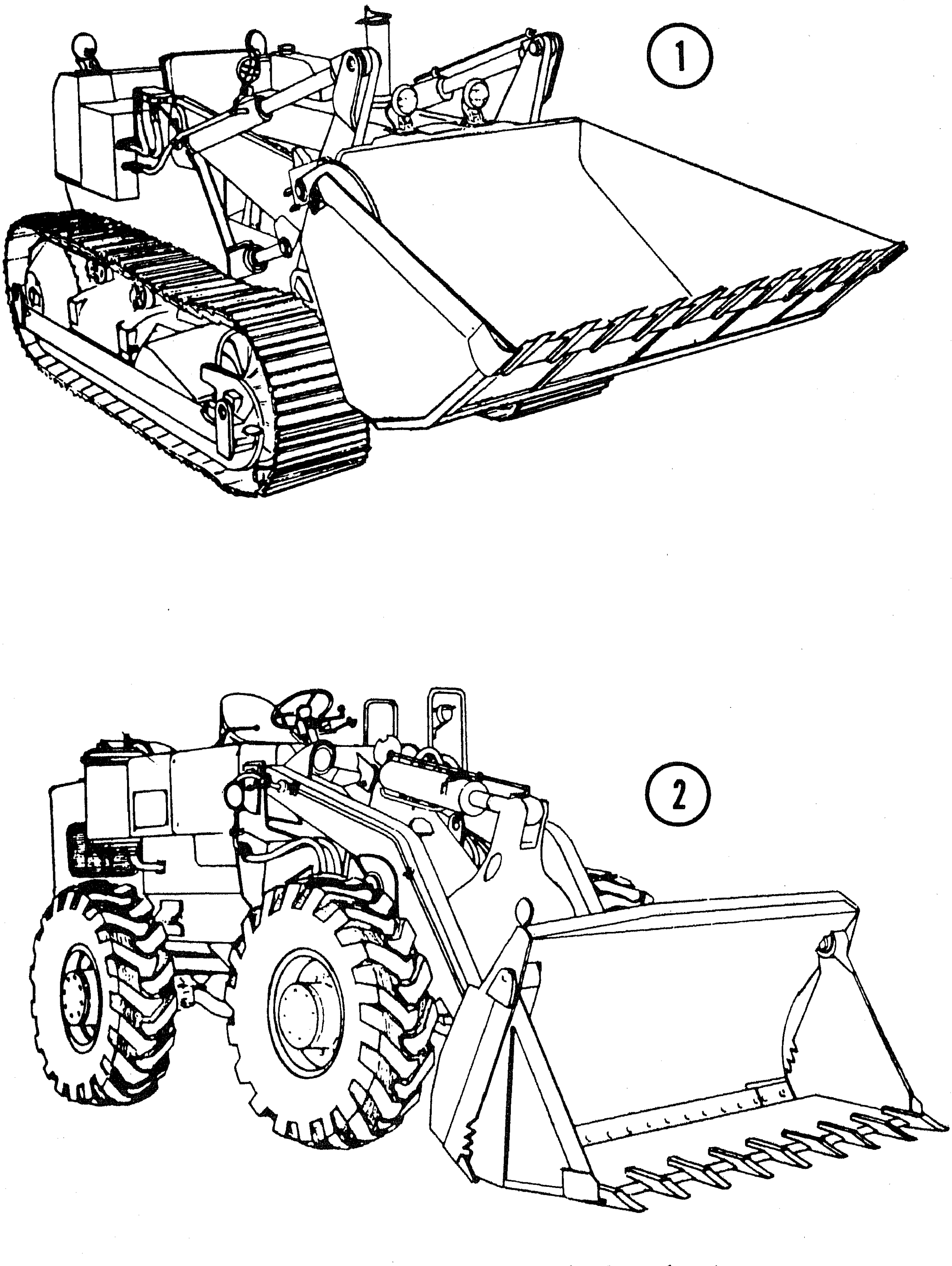
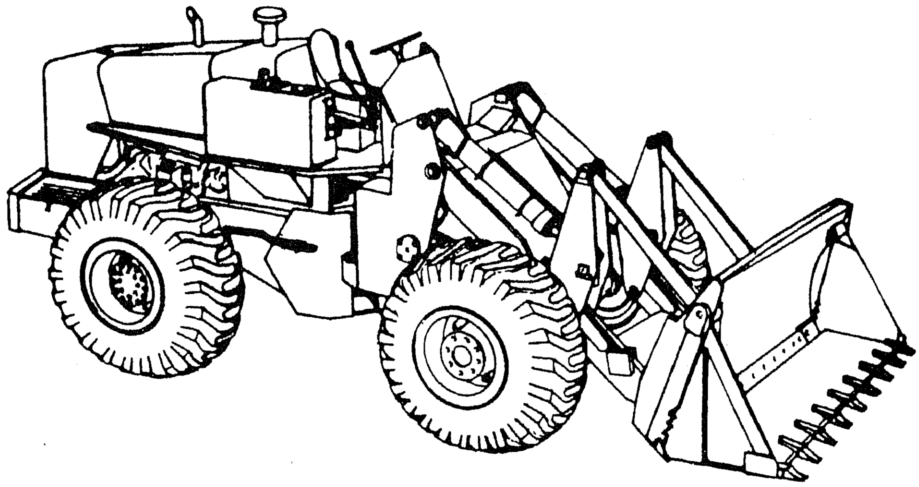


Figure 3-1. Scoop loaders with shovel attachment.

1



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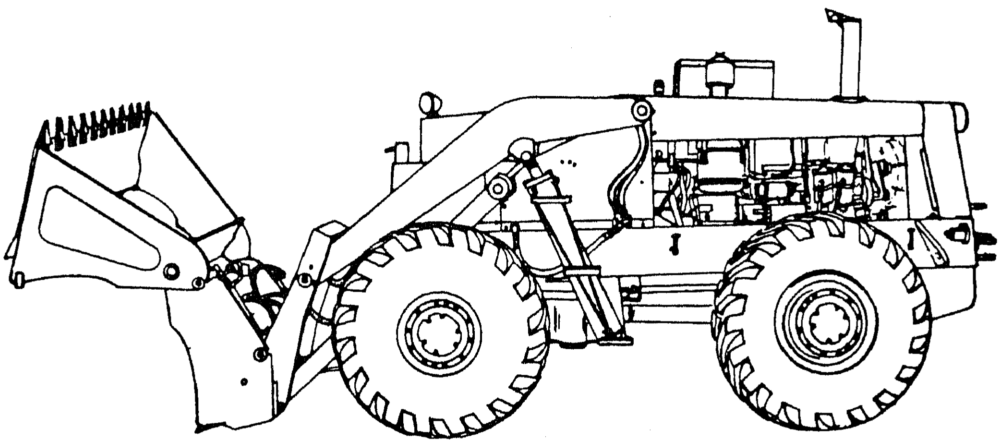

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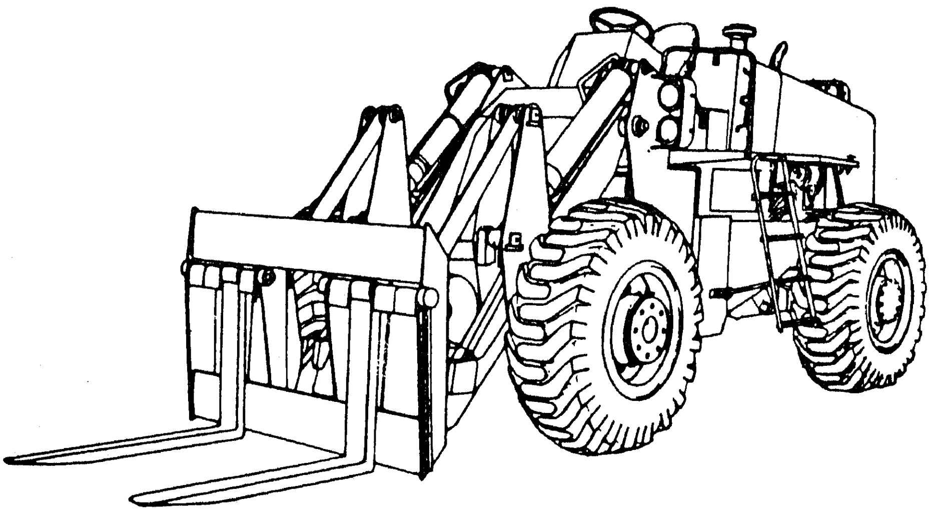


Figure 3-2. Scoop loader with clamshell-dozer and forklift attachments.

job site to another, and is capable of maintaining 20 mph in convoy. The power shift transmission with torque converter gives the loader fast movement both forward and reverse with a minimum of shock and enables the machine to maintain a high rate of production. The large rubber tires provide good traction on unstable surfaces and allow the loader to perform on side slopes of 15 percent and on straight slopes up to 30 percent in the direction of travel. The hydraulic system gives the operator positive control of the mounted attachment and provides an assist in steering. Pintle or towing hooks are provided on the machine for towing small trailers or light loads.

b. Tracked Loaders. Mounted on crawler tracks, the loader has a low ground bearing pressure which enables it to operate in areas that would be inaccessible to rubber tired loaders. The tracked loader normally has a flat track pad that allows it to work on hard paved surfaces with a minimum amount of damage to the surface. The tracked loader has a relatively low speed which greatly reduces its mobility capability. However the loader can negotiate side slopes of 35% and 60% slopes in the direction of travel. A hydraulic system provides positive control of the mounted attachments. A drawbar is mounted on the rear of the loader to facilitate towing of loads.

3-3. Scoop Loader Employment

The scoop loader is a versatile and capable item of equipment. It can be utilized in all zones of operation and can dig at ground level, above ground level and below ground level. The loader can travel from one construction site to another under its own power and does not require another item of equipment to level, smooth, or clean up an area in which it has been working. Typical uses of the scoop loaders are stockpiling materials, digging gun emplacements, backfilling ditches, loading trucks, lifting and moving construction materials, and when equipped with rock type tread tires can operate efficiently in and around rock quarries.

a. Excavations. A loader can dig excavations such as basements or gun emplacements if the material to be excavated is not too hard. In so doing it must construct a ramp into the excavation in order to bring the material out (fig. 3-3). A combination of the loader and haul trucks will increase the efficiency more than threefold.

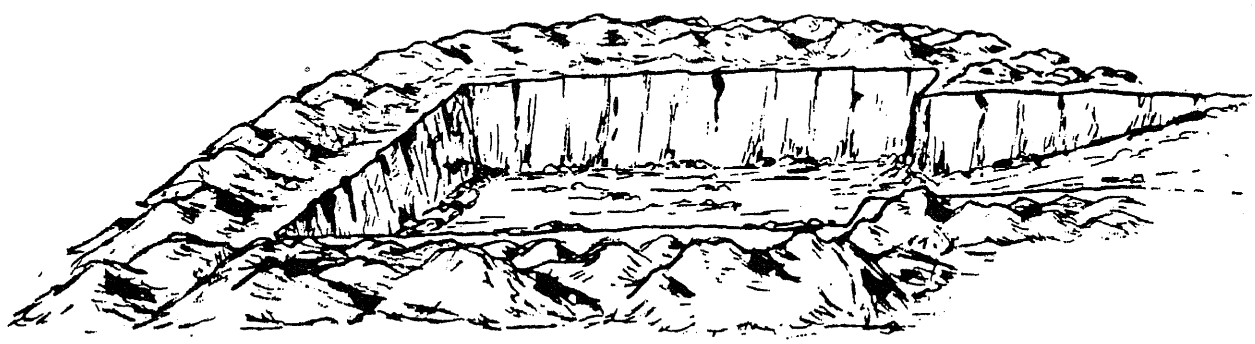


Figure 3-3. Plan of emplacement constructed with a scoop loader.

b. Backfilling. The loader can be utilized in operations such as backfilling ditches or trenches. An advantageous feature is that the rubber-tired unit's tires have a minimum tearing effect when working on a hard surfaced area such as asphalt. By lowering the bucket to grade level, the forward movement of the machine will push the stockpiled earth into the trench (fig. 3-4). This work is ideal for the scoop loader as long as the bucket is as wide or wider than the tracks or wheels to insure clean up in the least number of passes.

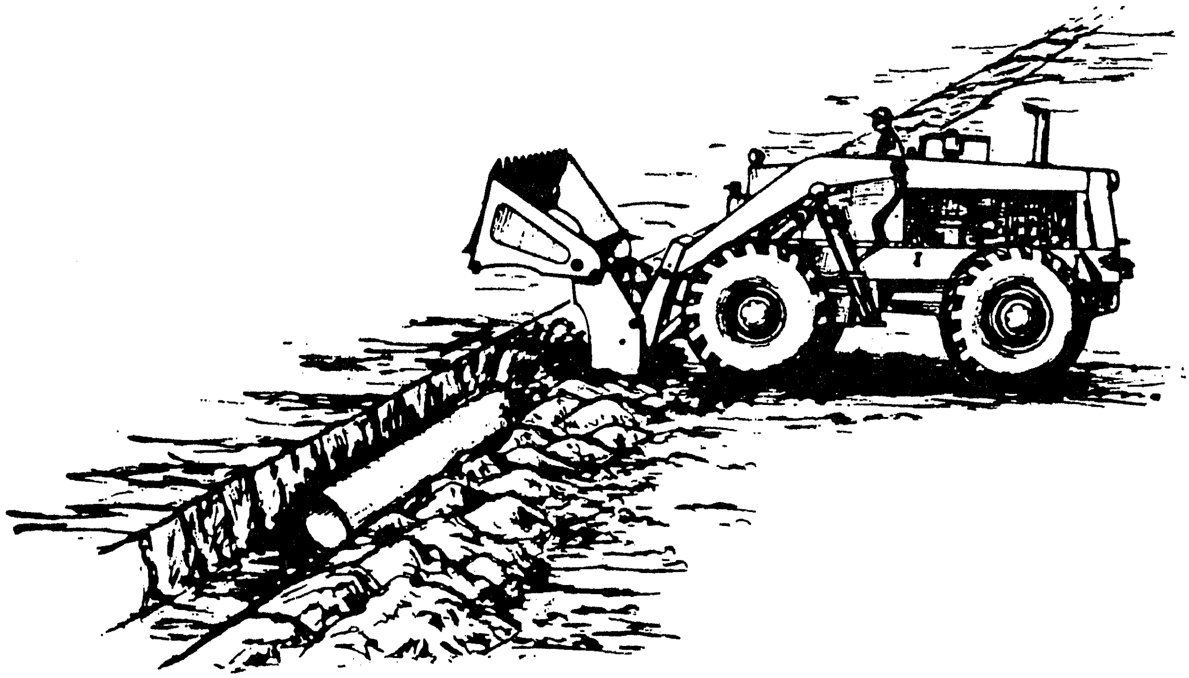


Figure 3-4. Backfilling with a scoop loader.

arrow buckets cause the tracks or wheels to de up the stockpile. This raises one corner of e bucket and reduces the area for cleanup.

c. Loading Trucks. The procedure for load- g trucks from a bank or stockpile is to head e loader toward the bank or pile in low gear ith the bucket lowered almost touching the 'ound. As the bucket enters the material it ıould begin to raise, moving forward until it filled. The upright loaded bucket should be aced in a hold position and backed away om the stockpile or bank. While these ma- ıines are flexible and can dig under very vkward conditions, best production is ob- .ined if both the angle of turn and moving stance are kept to a minimum. In loading 'om a stockpile or bank with a single loader, ıe loader makes a frontal approach to the ınk and the truck is positioned at about a 5° angle to the face (fig. 3-5).

d. Other Uses. The scoop loader is often utilized on the many miscellaneous tasks found in construction work such as stripping over- burden; charging hoppers and skips; carrying concrete to forms; lifting and moving con- struction materials, forms, large concrete and steel pipes; assisting in plant erection and maintenance activities such as loading and off-loading small generators, water pumps, and engines. The loader is also utilized to tow smaller trailers and light loads.

3-4. Scoop Loader Production

The production of scoop loaders will be af- fected by numerous factors which must be con- sidered prior to their employment. Among the factors are: operator skill, extent of prior loosening of the material, weight and volume of the material, slope of the operating area, height of the material, climatic conditions, and management factors. For planning pur- poses or as a guide, refer to table 3-1, and figure 3-6.

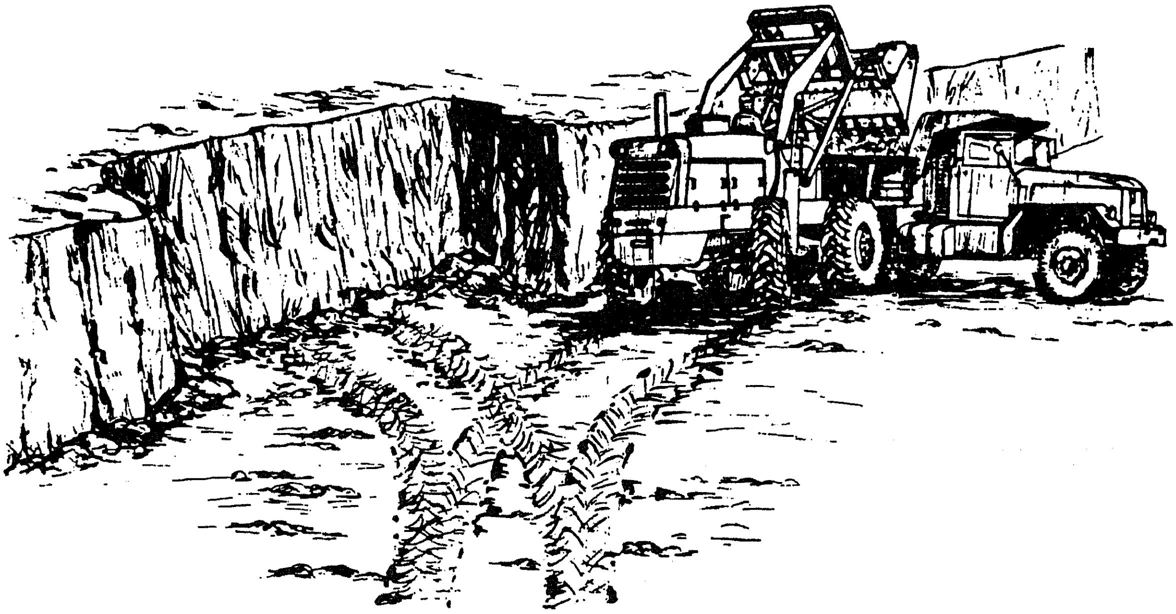


Figure 3-5. Loading trucks with a scoop loader.

Table 3-1. Scoop Loader Production in Cubic Yards per Hour Based on a 50 Minute Hour.

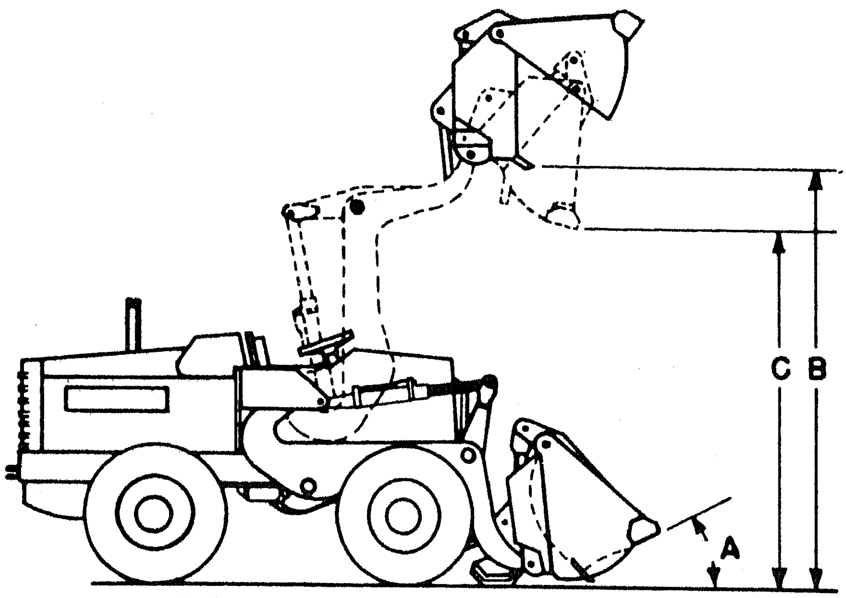
SAE Rated Bucket apacities (cu yds)	Cycle Time In Seconds										
	20	30	40	50	60	80	100	120	140	160	180	20
1	150	100	75	60	50	38	30	25	21	--	--	-
1½	220	150	110	90	75	55	45	37	32	28	25	2
2¼	338	220	168	132	110	85	68	56	48	42	38	3
2½	370	250	185	150	125	94	75	63	54	47	42	3
3½	---	342	260	210	175	160	110	86	75	65	58	5
4	---	395	300	240	200	150	120	100	85	75	66	6

3-5. Techniques of Operation

There are operating techniques that improve production when utilizing scoop loaders. For example, when loading the bucket it should be parallel with the ground, the cutting edge skimming the surface being traveled, removing ruts, obstacles, and loose material on the forward pass of the machine. The loader should be moving at slow speed, increasing power as the cutting edge contacts the bank or stockpile. Upon penetration of the material the bucket should be raised. Crowding material into bucket and rolling back of the bucket will pr vent the spilling of the material.

a. Proper Positioning. Proper positioni of equipment to receive material from t loader is necessary for maximum productio to cut down on maneuvering time and avoid damage to the traveled surface.

b. Difficult Material. To maintain efficien when handling a sticky material that has tendency to cling to the bucket, the mul segment bucket with its clam type opening more advantageous than the solid bucket. Co



	MAKE AND MODEL				
Specifications	Michigan 85 AM	Clark 175 AM	Hough H-90M	Hough H-90 CM	Allis-Chalmers 645M
SAE Rated Capacity (cu yd)	1-1/2	2-1/2	2-1/4	2-1/2	2-1/2
Maximum Tiltback (Degrees) (A)	40°	40°	40°	40°	41°
Clearance When Bottom Dumped (B)(ft)	-	-	12'	11'4"	11'9"
Cutting Edge Clearance at 40° Dump Angle (C)(ft)	7'8"	8'6"	10'	10'	8'6"
Overall Width (ft)	6'10-1/2"	8'9"	8'5"	8'5"	8'5"
Maximum Lift Capacity (In Place)(lb)	9,000	15,000	18,000	15,000	19,500
Maximum Carrying Capacity (lb)	6,900	7,000	8,000	8,000	8,000
Maximum Speed Forward (mph)	26	27	29	28.1	21.9
Maximum Speed Reverse (mph)	26	27	29	28.75	7.7
Outside Turning Radius (in)	212"	282"	276"	276"	279"
Digging Depth (in)	12"	16"	-	13"	13"

Figure 3-6. Working ranges for wheel-mounted scoop loaders.

versely, when handling (digging) material that is medium to hard, greater efficiency can be achieved if this material is broken up or loosened first by the use of a rooter, ripper, or by explosives.

c. Selection Factors. Certain factors enter into the selection of a scoop loader or other item of equipment to perform a task. One of these is the volume of material to be excavated. Scoop loaders are excellent machines to utilize in soft to medium material, such as that found in stockpiles. When the material is medium to hard the production rate of the scoop loader is greatly reduced. Further, a scoop loader attains its highest production rate when it works flat smooth-surfaced areas and has proper space to maneuver. If there are poor underfoot conditions and lack of space to operate efficiently, some other item of equipment may be more effective. The height that the material must be placed or dumped is another factor which must be considered as other items of available equipment may construct a stockpile faster or load a hopper or grizzly more efficiently.

Section II. FORKLIFTS

3-6. Introduction

Forklifts, generally known as materials-handling equipment, were formerly restricted to use in warehouses or terminals. The Army now has two types of forklifts for other purposes. The first is a result of replacing the bucket on a scoop loader with a forklift attachment. This modified machine has not been widely used and will not be discussed further in this volume. On the other hand, the rough terrain forklift (RTFL) (fig. 3-7) now provides

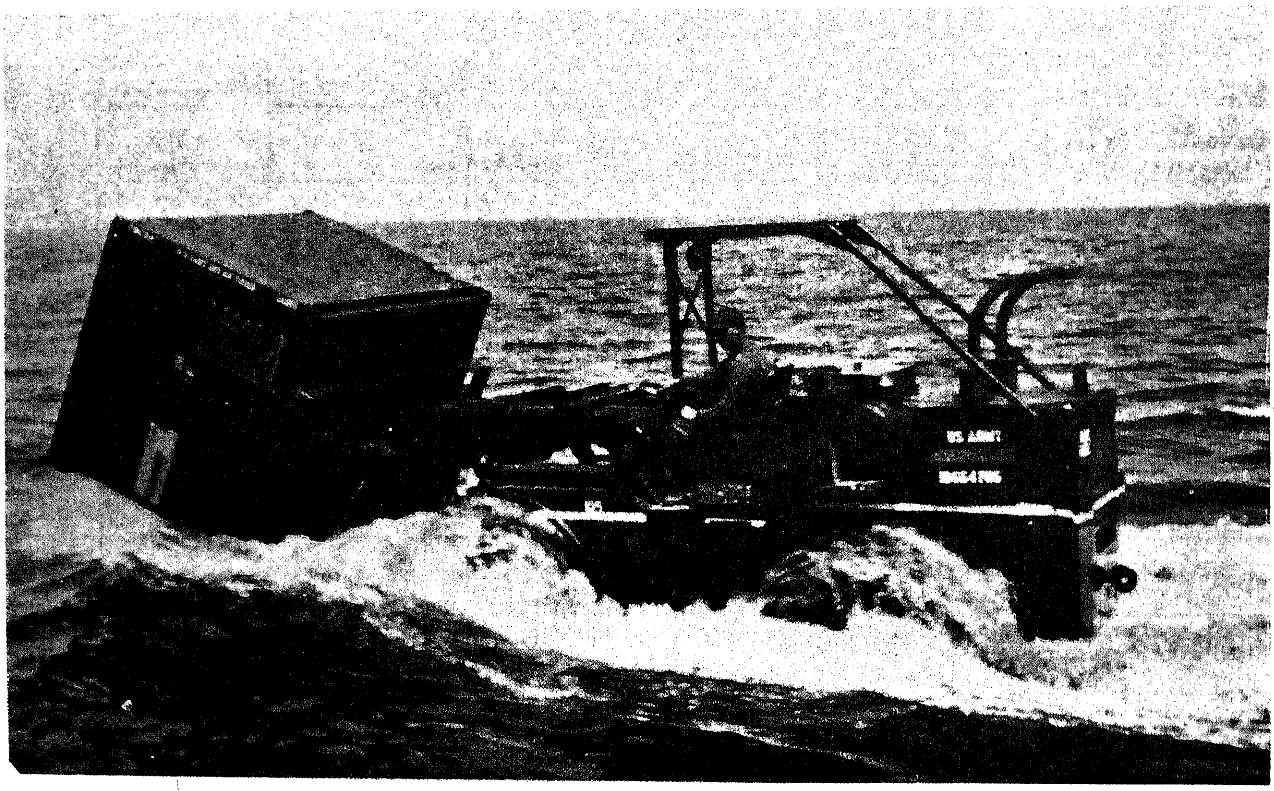


Figure 3-7. Rough terrain forklift.

handling for missiles (Nike-Hercules) at firing batteries; loading and unloading flatcars, military trucks, flat trailers, aircraft, and Naval landing craft; and stocking and transporting heavy crates and palletized loads of heavy supplies over unprepared, unstabilized surfaces, expecially over rough terrain, such as over-the-beach, in 5 feet of surf, in deep sand, snow, and mud where high flotation is needed. It can be moved at high speed without load between operation sites.

3–7. Characteristics and Capabilities

There are two RTFL sizes currently in the military. Their rated load capacities are 6,000 and 10,000 pounds. They both are diesel-engine driven and have operator-selected 2- and 4-wheel drive and 2- and 4-wheel steering. They have front- and four-wheel positive hydraulic steering. Four-wheel steering permits the operator to both cramp (rear wheels turning in the opposite direction of the front wheels) and crab (rear wheels turning in the same direction as the front wheels). The physical characteristics are shown in table 3–2.

3–8. Techniques of Operation

a. When positioning the truck to pick up a load, it should be brought in square to the load. The side shift should then be used to aline the forks rather than trying to aline the whole truck. Loads at an angle may be easily picked up with use of the oscillation.

Table 3–2. Characteristics and Capabilities of Rough Terrain Forklift.

Dimensions	*Forklifts* 6,000 pound	10,000 pound
Width	8′–6½″	8′–10″
Length		
Without forks (with fork in carry position)	17′–0″	17′–0″
With forks (with fork in carry position)	21′–0″	22′–00″
Height		
Without guard	8′–4″	8′–4″
With guard	10′–0″	10′–0″
Wheel base	8′–4″	9′–0″
Weight (with forks) (lb)	23,000	34,000
Drawbar pull (lb)	20,000	30,000
Load capacity (lb) at 24″ load centers*	6,000	10,000
Lift height (in.)	144	144
Fork tilt (degrees)		
Rear	90	90
Forward	90	90
Lift speed (ft per min)		
With rated load	50	50
No load	84	84
Truck rotation (osillation right or left of center) (degrees)	10	10
Speed (mph)		
Empty		
Forward	32	26
Reverse	25	26
Loaded		
Forward	26	20
Reverse	26	20
Turning radius		
Outside	15′	17′
Inside	7′	8′
Ground clearance	1′–2″	1′–2″
Reach below ground (without load) (in.)	4	4
Gradability (slope) (percent)	45	45
Side stability (slope) (percent)	30	30
Fording depth (to crest of wave (ft)	5	5

* Center of gravity is not more than 24″ in front of fork.

Normal material handling work should be done in 4-wheel steer, with 2-wheel steer for high-speed runs.

b. To accelerate movement of the fork and boom, use the left brake pedal to disconnect the drive-line while racing the engine. Should any of the wheels spin out, the far left pedal on the 6,000 lb truck should be depressed for wheel lock-up.

c. The boom should be extended for normal usage and retracted against the frame for transporting.

d. For operation in sea water, disconnec the fan with the lever, and use four-whee drive.

e. Tire pressure may be lowered 10 psi whe on sandy or muddy terrain.

f. If caught in a rut, use of crab steer w:l often assist in driving out.

g. The engine emergency shut-off shoul not be used for routine shut-down as this wil damage the seals. It must be reset after eac use.

CHAPTER 4

HAULING EQUIPMENT

4-1. Availability and Characteristics of Trucks

The hauling equipment most commonly available for military construction are the 2½- and 5-ton rear-dump trucks (figs. 4-1 & 4-2) which is organic equipment in most engineer units. Found also in limited quantities, in quarry operating units, is the off-the-road 20-ton rear dump truck (fig. 4-3) with a rock or quarry type body. Cargo trucks, also organic to most engineer units, can be used as expedients when dump trucks are not available (TM 5-331E). Cargo trucks are also available from transportation truck companies or battalions. Physical characteristics of dump trucks are shown in table 4-1.

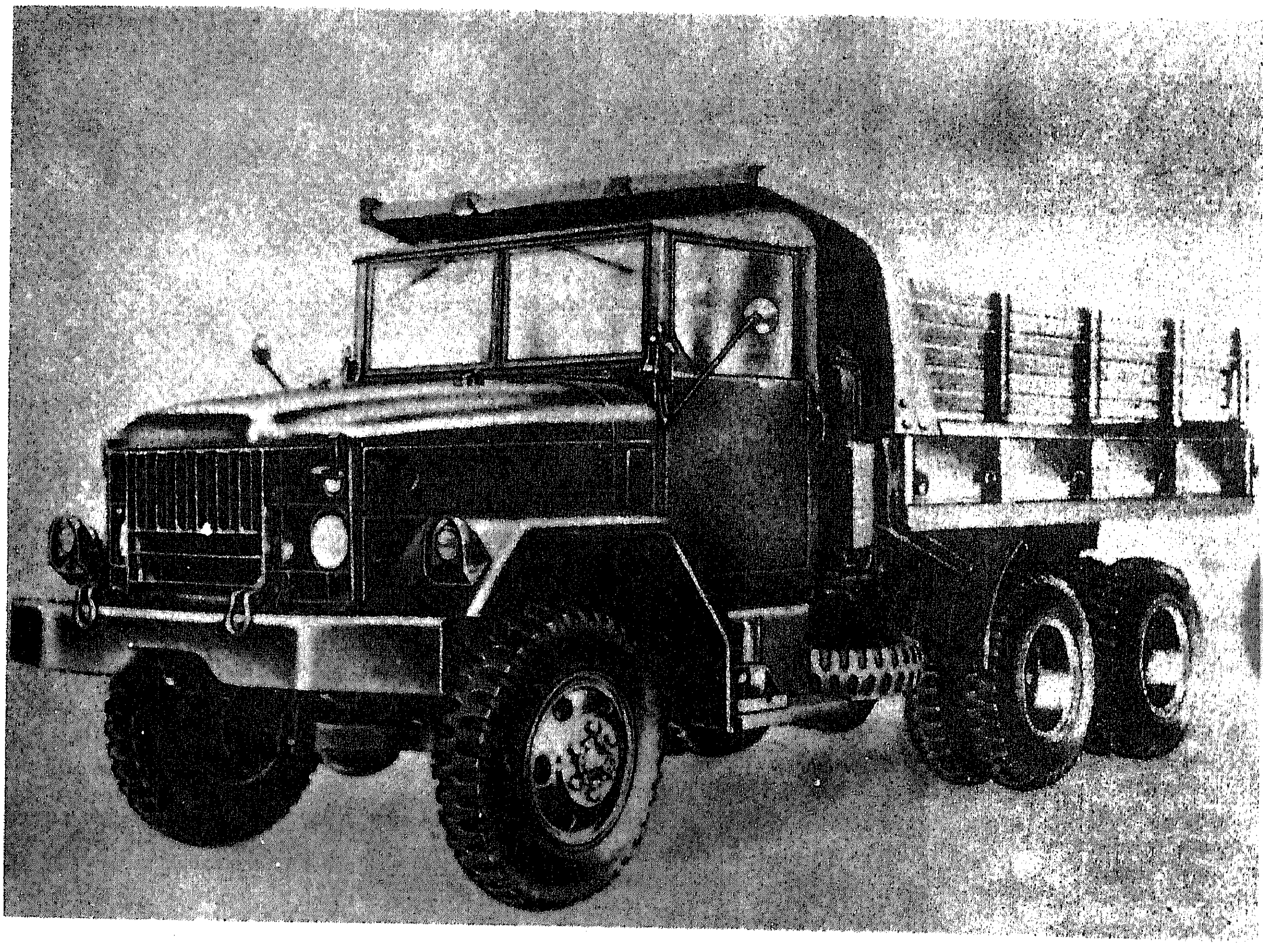


Figure 4-1. 2½ Ton rear-dump truck.

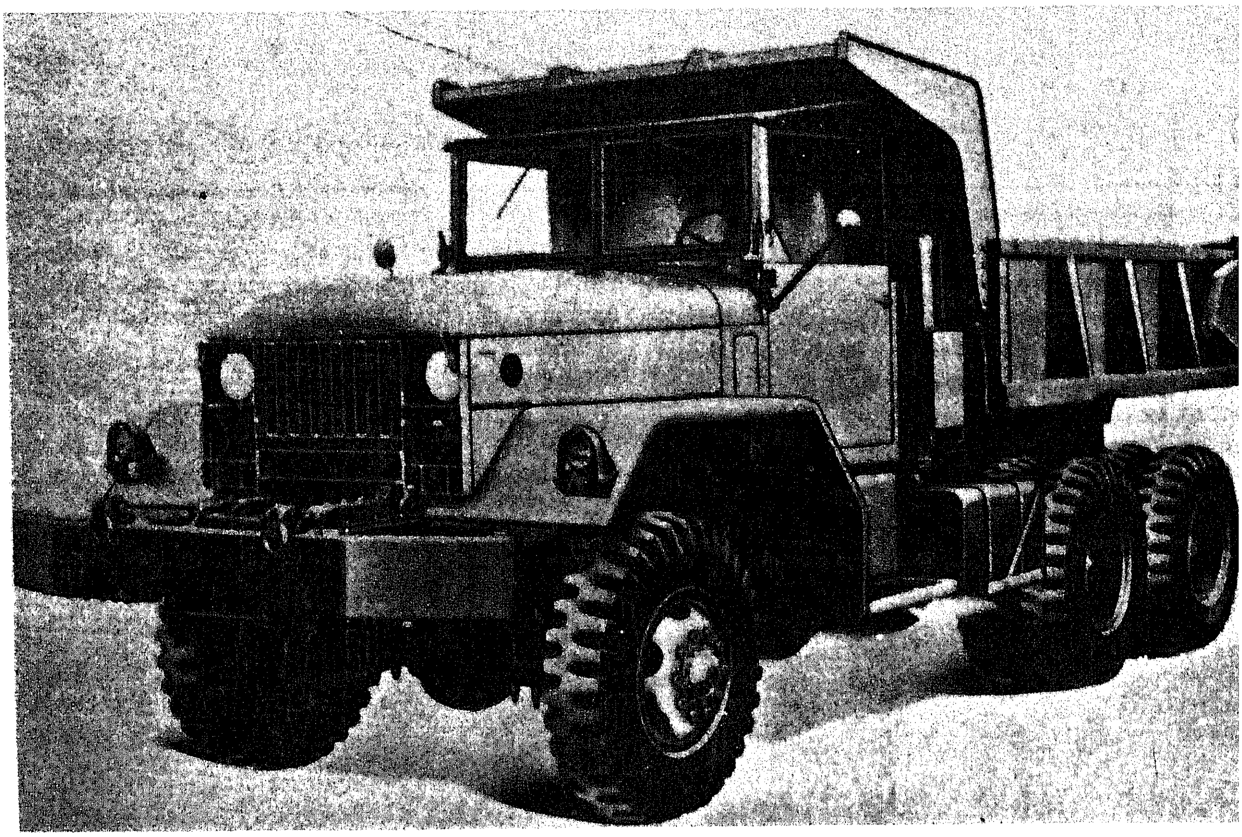


Figure 4-2. 5 Ton rear-dump truck.

Table 4-1. Physical Characteristics of Hauling Trucks

Truck	Weight Net (lb)	Payload (lb)	Overall length (in.)	Overall width (in.)	Overall height (in
Cargo, 2½ ton 6 x 6:				96	97
with winch	23,915	10,000	336		
without winch	20,000	10,000	322		
cross-country.		5,350			
Cargo, 5 ton 6 x 6:				97	110
with winch	20,535	20,000	314¼		
without winch	19,480	20,000	298¾		
cross-country.		10,000			
Dump 2½ ton 6 x 6:				96	108
with winch	15,580	10,000			
without winch	15,165	10,000			
cross-country.		5,000			
Dump 5 ton 6 x 6:				97	110⅝
with winch	22,664	20,000	281⅝		
without winch	21,981	20,000	266⅛		
cross-country.		10,000			
Dump 20 ton 4 x 2	33,400	40,000	302	121	138½

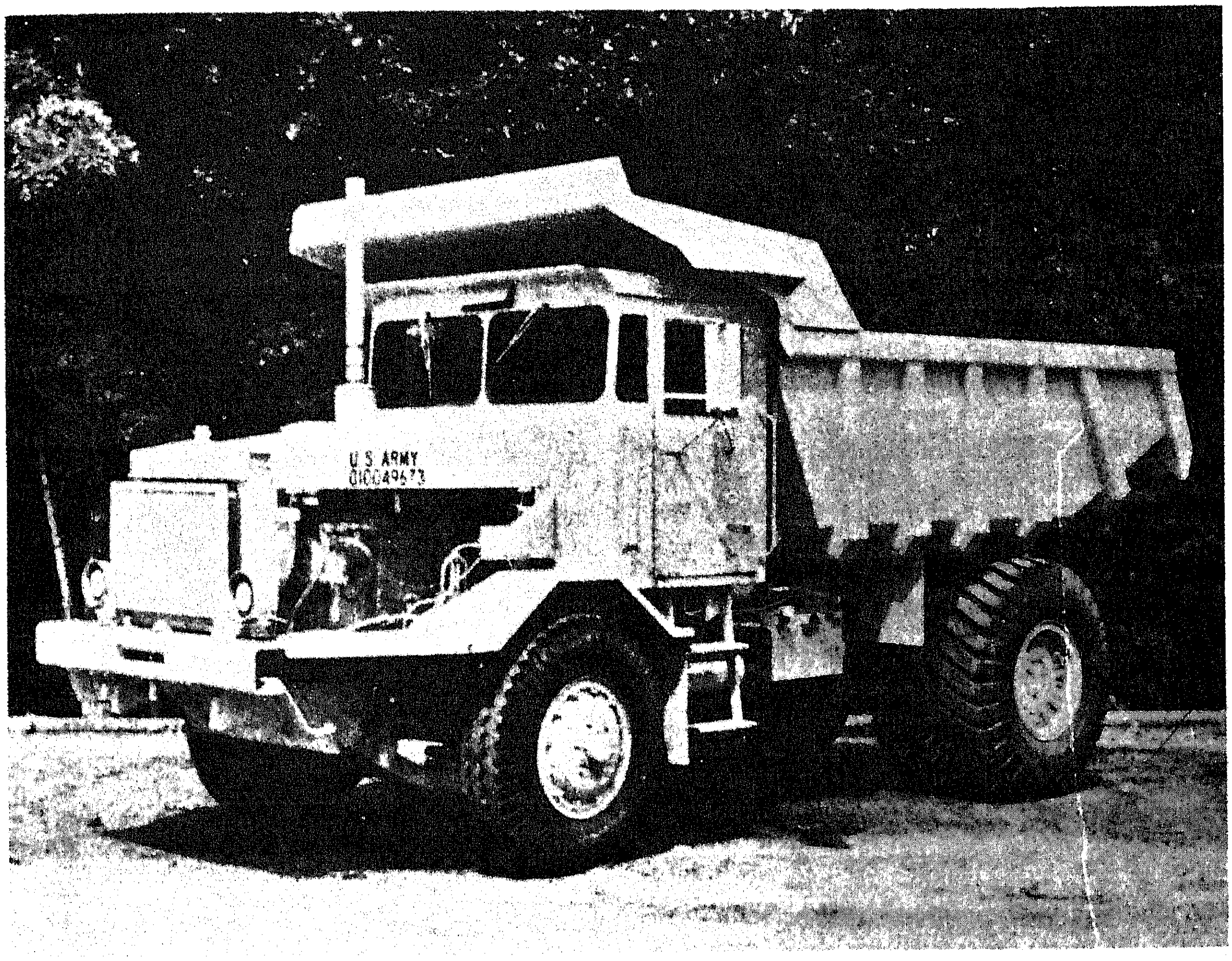


Figure 4-3. 20 Ton rear-dump truck.

4-2. Use of Dump Trucks

Dump trucks are used for a variety of purposes. Primarily however, dump trucks in the context of this volume are used for hauling, dumping, and spreading base course and surfacing materials; for hauling other material incident to construction operations; and for general hauling where the distance is greater than 1,500 feet.

4-3. Capacities of Dump Trucks

Capacity of a piece of hauling equipment, including dump trucks, is expressed in at least three ways—by the load it will carry expressed in tons, by its truck volume expressed in cubic yards, or by its heaped capacity also expressed in cubic yards. The capacity of Army dump trucks is always expressed in tons. However, the material and capacity of the loading equipment is expressed in cubic yards. The unit weight of the various materials that may be transported may vary from as little as 1,700 pounds per cubic yard for dry clay, to 3,888 pounds per cubic yard for concrete. (See FM 5-34 for weights and conversion factors of common materials). Care must therefore be taken to assure that the weight capacity of the truck is not exceeded.

4-4. Determination of Number of Trucks Required

a. Formula. The following formula is used to make a preliminary estimate of the number

of trucks required to keep the loading equipment in operation at highest capacity:

$$N = 1 + \frac{\text{Travel cycle (min)}}{\text{Loading time (min)}}$$

(1) The travel cycle is the time that is required for a hauling unit to complete one cycle of operation and may be determined by actual measurement. For example, the time for a loaded dump truck to pull away from the loading equipment, travel to the site where the material is required, unload, return to the loading unit, and be reloaded is one complete cycle.

(2) The loading time is the time required for the loading equipment to actually load the truck, plus the time which may be lost by the loading equipment while waiting for the truck to be spotted.

(3) The numeral "1" in the formula is a safety factor against the necessity for closing down the loading equipment due to lack of hauling equipment. If all operations are on schedule one truck will be standing by, ready for spotting, at all times.

b. Changes in Requirements. The productive ability of the loading equipment is normally a controlling factor on jobs requiring use of haul units, i.e. loading equipment should never be kept waiting. After the job has started it may be necessary to change the number of trucks required due to changes in haul-road conditions, reduction or increase in length of haul, or conditions at either the loading or unloading areas.

c. Standby Units. Since the product ability of the loading equipment will be p tially wasted if there are not enough trucks take the material away, it is most import to provide not only ample haul capacity ba on a normal cycle time but also stan trucks which can be put into operation quic to replace any trucks that have mechan trouble. The number of standby trucks pends largely on the mechanical condition the trucks as well as the size and importa of the job. In small fleets serving a sir loading unit, the ratio of standby trucks active trucks may be as high as one to f On larger jobs, the ratio is smaller. Stan trucks need not actually be idle, but may employed on lower priority tasks from wh they can be readily diverted.

d. For a hasty method of determining number of trucks required, use table 4-2.

4-5. Techniques for Maximum Output o Dump Trucks

The following techniques assist supervisor obtaining maximum hauling efficiency.

a. Trucks should be started and stoppe staggered intervals when practicable, in o to reduce time losses resulting from "bunch up"

b. The dump trucks should be filled to maximum extent practicable. If haul r are in poor condition or the material is ex sively heavy, care must be taken not to o

Table 4-2. Number of Trucks Required to be Spotted[1]
Haul units needed to spot per hour under shovel in medium digging

Size shovel digger (cu yd)	Approx shovel cycle time (in seconds)[2]	Loading time for 4-dipper truck (in seconds)	Interval (in minutes) for spotting trucks	Number of trucks need at the shov per hour
⅜	18	72	1.2	50
½	18	72	1.2	50
¾	20	80	1.33	45
1	20	80	1.33	45
1¼	20	80	1.33	45
1½	20	80	1.33	45
2	20	80	1.33	45
2½	22	88	1.46	41

[1] Table based on a shovel efficiency factor (E) and dipper efficiency factor (K) of 100 percent.
[2] 90° swing, no delays, loading on grade.

load the trucks. Equipment out of service because springs, axles, or transmissions were broken, while operating under overload conditions, more than offsets the production gained from maximum loads.

c. Dump bodies should be kept clean and in good condition. Accumulations of rust, dirt, dried concrete, or bituminous materials hamper dumping operations.

d. Attention should be paid to the location of the load within the dump body. Heavier materials should be placed near the rear of the body to minimize the work of the dumping mechanism.

e. The walls and sides of dump bodies may be oiled with diesel oil or used crankcase oil to prevent bituminous materials from sticking. They should be thoroughly cleaned between each load and at the end of the day's operations. When the trucks are to be used to haul concrete, the bodies should be sprayed with water before loading and should be thoroughly cleaned as soon as practicable after the load is dumped. It must be remembered that the time spent in cleaning and oiling truck bodies must be considered in computing transportation requirements.

f. Spotting logs or blocks are generally used when trucks are hauling from a hopper, grizzly ramp, or stockpile. They are also beneficial when hauling from a crane-shovel, where they facilitate the prompt and accurate spotting of the vehicle. This improves the shovel operator's time in loading and speeds the loading operation. When being loaded by a shovel the trucks should be spotted as close to the bank as possible within the radius of the dipper as it leaves the bank (fig. 2–12). This saves time in racking the dipper in and out. Care must be taken to assure that the shovel does not unload over the truck cab.

g. Hauling should be done at the highest safe speed and in the proper gear without speeding. Speeding is an unsafe practice, is hard on equipment, and causes delays by throwing the fleet out of balance.

h. A sluggish truck should be replaced by a standby truck until the maintenance crew can check and adjust it. A slow truck, as well as a speeding one, will disrupt the normal traffic pattern.

i. Separate haul roads to and from the dump are desirable. They should be well maintained, and grades should be kept to a minimum.

j. Traffic pattern for loading and unloading should be laid out that will minimize backing and passing.

k. When dumping material that requires spreading by a dozer or a grader, the truck should be moved forward as the load is dumped, in order to reduce the spreading effort.

l. When poor footing or difficult spotting causes slow dumping, alternate dumping locations should be established in order to maintain truck spacing.

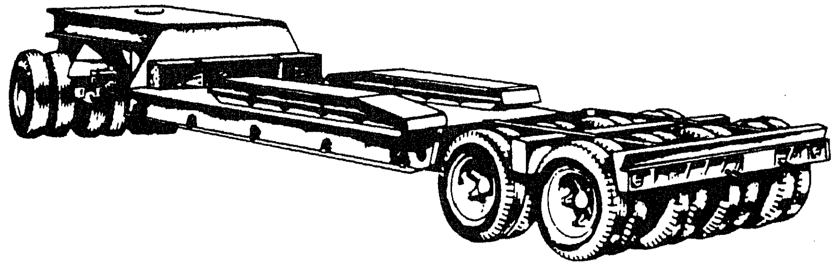
m. Tallymen may be stationed at the unloading points to keep accurate records of the number of loads hauled by each truck. These records serve in preparing production records and in locating individual irregularities that may warrant further investigation.

4–6. Equipment Trailers

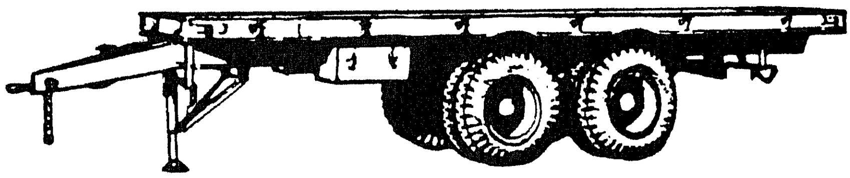
a. Physical Characteristics. Table 4–3 list types, capacities, dimensions weights, and operating characteristics of equipment trailers.

b. Use. Equipment trailers (fig. 4–4) are used for rapid transportation of heavy construction equipment, such as crane-shovels, concrete mixers, and any other tracked, skid-mounted, or wheeled equipment not designed for movement by other means. They are also widely used on construction projects to haul long items, such as pipe or lumber, or packaged items, such as landing mat or bagged cement. Maximum efficiency is obtained when trailers are loaded as closely as possible to their rated capacities.

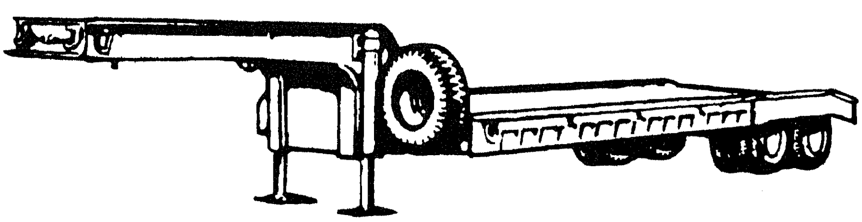
c. Techniques for Maximum Output. The following techniques help equipment supervisors obtain maximum efficiency in the use of trailers.



TRAILER LOW BED



FLATBED TRAILER



SEMITRAILER

Figure 4-4. Equipment trailers.

Table 4-3. Characteristics of Equipment Trailers

Body Type	Capacity	Net	Payload	Gross	Length	Width	Height	Loading Height
	Tons	*Lb.*	*Lb.*	*Lb.*	*In.*	*In.*	*In.*	*In.*
Trailer, Flatbed	8	9,000	16,000	25,000	293	90	57	36
	10	11,260	20,000	31,260	276	98	54½	54½
Semitrailer, low bed	25	14,866	50,000	64,860	414	115	68	36
Trailer, low bed	60	34,000	120,000	154,000	554	122	64	33

(1) *Maintenance.* Each trailer has a specific individual assigned to perform the preventive maintenance duties. The assistant driver of the regularly assigned prime mover can be used, but during multiple-shift operations, when the assistant drivers are on a regular run, it may be necessary to assign several trailers to an individual in the motor pool. Air brakes and hand brakes must be checked before and after each trip.

(2) *Loading.* With rear loading trailers, low banks or built-up earth ramps are used where possible; however, loading ramps for loading from level ground are carried on these trailers at all times. In loading with ramps, a crawler-mounted machine is run slowly up the ramp and, as the balance point is reached, speed is reduced to permit the equipment to settle gently onto the trailer bed. Care must be exercised to prevent stall-out and possible run-away. It is then moved slowly ahead until it rocks forward on to the trailer. In all loading, a man is stationed on the trailer to direct the equipment operator and keep the machine centered on the ramp and the trailer. The trailer may be loaded from the side in areas that restrict end loading, but care must be taken to avoid damage to the trailer bed.

(3) *Securing equipment on trailer.* All equipment is blocked and checked in position and chained to the trailer bed. Care must be taken to properly distribute the weight of large equipment on the trailer. Equipment trailers are normally marked at proper centering position.

(4) *Unloading.* Heavy equipment is unloaded slowly to prevent damage to the trailer or to the equipment. Trailers are generally unloaded over the end but site conditions may sometimes necessitate unloading over the side. The "jumping" of equipment from the bed of the trailer to the ground or to embankmer not suitable for ramps must not be permitt

CHAPTER 5

SAFETY

-1. Introduction

me is usually the controlling factor in con- ruction operations that require the use of en- neer equipment, particularly in the theater operations. The necessity for economy of ne, coupled with the temporary nature of uch of the work being done, sometimes re- lts in the use of safety precautions which e substantially lower than those used in ci- lian practice. Such lowered safety standards ould *not* be used as a general practice, but ly in cases of extreme urgency. Relaxed neral safety requirements may result in mporary increases in production but the *vantages so gained are often negated by mage to facilities or equipment, or by in- ry, and sometimes death, to personnel.* Sub- quent paragraphs give the basic safety rules iich should be followed in all operations in- lving the use of construction equipment. In cumstances where literal application of a quirement to a specific job has impractical pects, the commanding officers of separate stallations, activities, and units are author- d to approve an adaptation which meets e obvious intent of the requirement. For lp in making safety decisions, the safety formation contained in Corps of Engineers anual entitled "General Safety Require- nt", EM 385-1-1, should be reviewed for plicable safety methods.

-2. Indoctrination of Personnel

fety should be taught to the operator dur- g his operator training, but each job has own safety hazards which are peculiar to e particular operation. These hazards must identified, and a safety programs which ll reduce or eliminate them prepared. Once e program has been prepared it is the re- onsibility of supervisory personnel to see that it is carried out. Each person on the job should be given an initial indoctrination advising him of the hazards he may meet and the ways in which he can reduce or avoid them. He should receive continuing instructions during the progress of the job to make sure the objectives of the safety program are met. Personnel should be instructed to watch out for fellow workmen and warn them when they get into dangerous positions. Horseplay, wrestling, scuffling, practical jokes, or unnecessary conversation must be avoided during working hours.

5-3. Operators Qualifications and Requirements

a. Operators of construction and weight-handling equipment shall be tested and licensed in accordance Army Regulation 600-55 and/or 600-58. An apprentice or license applicant shall operate equipment only under the direct supervision of a licensed operator.

b. The operator of an Army vehicle or construction, or weight handling equipment shall be responsible for the safe operation of the item while it is assigned to him, and for the safety of his passengers and cargo.

c. An operator who is not physically able or mentally alert shall not be permitted to start work with any piece of equipment.

5-4. Operation of Equipment

Before any mechanized equipment is put into use on the job, it should be inspected and tested by a qualified person and determined to be in safe operating condition. Continued periodic inspections should be made at such intervals as necessary to assure its safe operating condition and proper maintenance. Any machinery or equipment found to be in

an unsafe operating condition should be tagged at the operator's position—"Out Of Service, Do Not Use," and its use prohibited until conditions have been corrected. Mechanized equipment must be operated only by qualified and authorized personnel. It shall not be operated in a manner that will endanger persons or property, nor shall the safe operating speeds or loads be exceeded. Equipment requiring an operator will not be permitted to run unattended. Mounting or dismounting equipment while in motion, or riding on equipment by unauthorized personnel, is prohibited. An operator should not be permitted to operate any machinery or equipment for more than 10 hours without a consecutive 8-hour interval of rest. All equipment not equipped to prevent overloading or excessive speed shall have safe load capacities and/or operating speeds posted at the operator's position.

5-5. Guards and Safety Devices

Guards, safety appliances, and similar devices are placed on equipment for the protection of personnel, and must not be removed or made ineffective except or the purpose of making immediate repairs, lubrication, or adjustment, and then only after the power has been shut off. All guards and devices must be replaced immediately after completion of repairs and adjustments. Equipment having a hoist or lifting capability should be provided with guards to prevent personnel from walking under the load.

5-6. Repairs and Maintenance

All equipment must be shut down or positive means taken to prevent its operation while repairs, adjustments, or manual lubrications are being made. Repairs should be made at a location and under conditions which will provide a safe place for the repairman. Heavy machinery, equipment, or parts thereof which are suspended or held apart by use of slings, hoists, or jacks must also be substantially blocked or cribbed before men are permitted to work underneath or between them. The hook, drag bucket, fork tines, and the like, should be lowered to rest on the ground or on suitable blocking when not in use.

5-7. Use of Signals

A uniform system of signals must be used on all operations of a similar nature. The system recommended for use in directing crane operations is shown in figure 5-1. The signals in use should be posted at the operator's position, at signal control points, and at such other points as necessary to properly inform those concerned. Where manual (hand) signals are used, only one person shall be designated to give the signals to the operator. This signalman must be located so as to be clearly visible to the operator at all times. Only persons who are dependable and fully qualified by experience with the operations being directed shall be used as signalmen. A signalman shall be provided whenever the point of operation is not in full and direct view of the machine or equipment operator. A warning device or services of a signalman shall be provided wherever there is danger to persons from moving equipment. Highway operated equipment should be equipped with turn signals.

5-8. Night Operations

All mobile equipment shall have adequate headlights and taillights when operating in hours of darkness. Construction roads and working areas shall be adequately lighted while work is in progress at night. Lighting shall be maintained until workmen have had an opportunity to leave the area. Personnel working in dark areas and exposed to vehicular traffic, such as signalmen, spotters, inspectors, servicemen, and others whose presence is required for a prolonged time, shall wear vests or other apparel marked with a reflectorized material.

5-9. Emergency Lighting and Signals on Airfield Construction

When equipment is used for loading aircraft, during construction, repair, or for any other purpose within the landing areas of operational air bases, safety precautions must be observed. The term "landing area" includes all runways, landing pads, and taxiways plus 75 feet on each side and a zone 1,000 feet long at each end of each runway, or to within

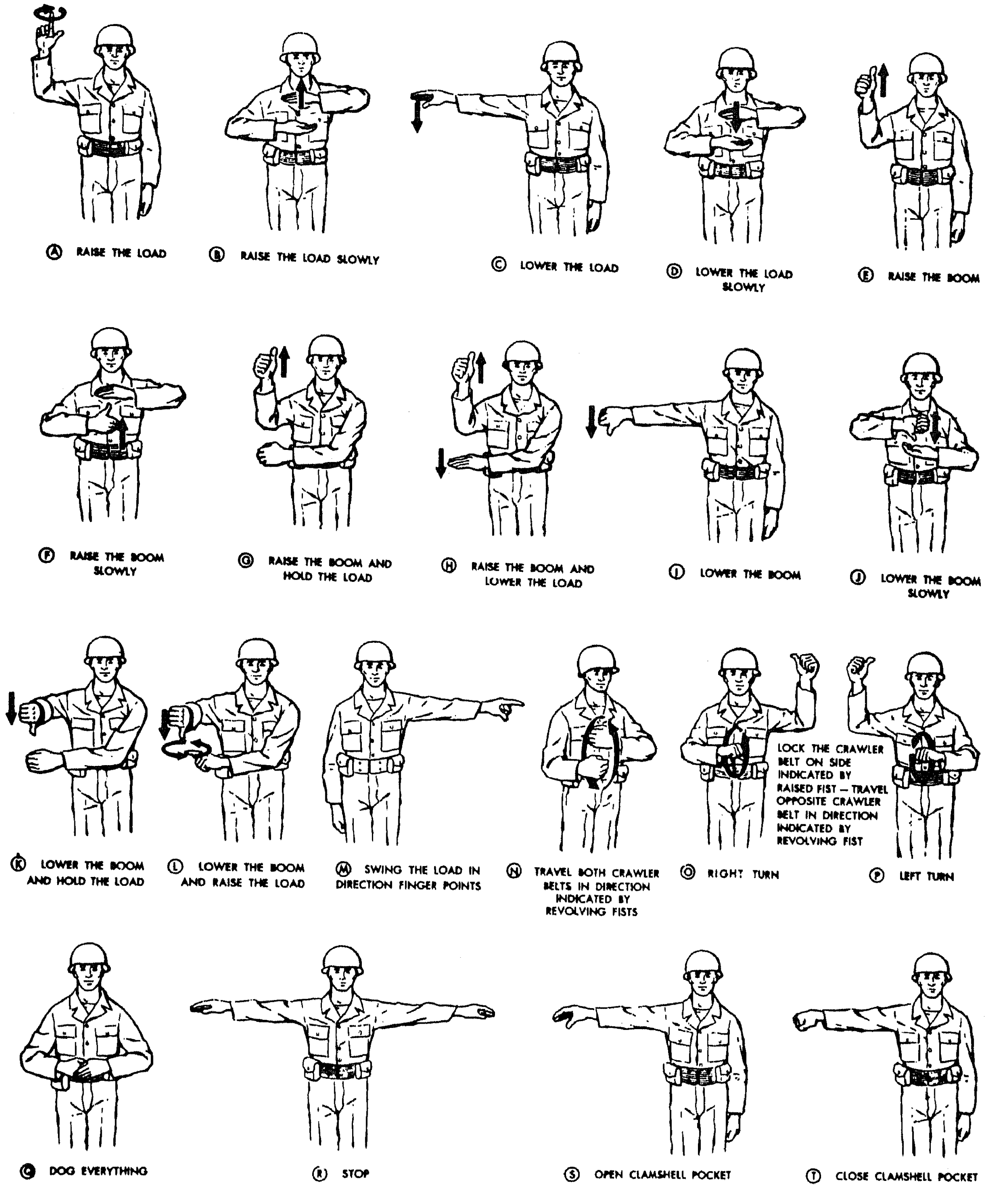


Figure 5-1. Hand signals for crane-shovel operations.

50 feet of the boundary of the airport. On allover landing fields, the entire area available for landing and taxiing of aircraft is included in the term. Landing areas hazardous to aircraft must be outlined by yellow flags by day and red lanterns by night, except that

where contact lights outline the runway no red laterns are required on the obstructions outside the contact area. Flags and lanterns shall be spaced not more than 200 feet apart. During daylight hours all equipment used in the landing area will be marked with international orange and white checkered flags and all material within the area with yellow flags. At night red lanterns must be used to mark both equipment and material. All flags used must be not less than 3 feet square and the checkered flags shall have alternate orange and white blocks of not less than *one* foot on each side and not less than nine squares for each flag.

5-10. Ropes and Cables

a. Introduction. The use of ropes and cables in construction operations presents one of the largest areas of potential safety hazards. These hazards can be eliminated through strict observance of load limitations placed upon them and through periodic inspection of their physical condition. The use of ropes, cables, and chains should be in accordance with the safe usage recommended by their manufacturers or within the safe limits recommended by the manufacturers of the equipment with which they are used. Tables 5-1, 5-2, and 5-3 contain recommended values for general conditions. When handling wire rope, leather gloves must be worn at all times.

Table 5-1. Properties of 6 x 19 Standard Wire Hoisting Rope [a]

Diameter (inches)	Approximate weight per 100 feet (lb)	(Breaking strength [b] (tons of 2,000 pounds)) Mild plow steel	Plow steel	Improved plow steel
¼	10	2.07	2.39	2.74
⅜	23	5.00	5.5	6.3
½	40	8.5	9.4	10.8
⅝	63	13.1	14.4	16.6
¾	90	18.7	20.6	23.7
⅞	123	25.4	28.0	32.2
1	160	33.0	36.5	42.0
1⅛	203	41.5	46.0	53.0
1¼	250	57.0	56.5	65.0
1½	360	72.5	80.5	92.5

[a] 6 × 19 rope means rope composed of 6 strands of 19 wires each. The strength of wire rope varies slightly with the strand construction and number of strands.

[b] The maximum allowable load is the breaking strength divided by the appropriate factor of safety. Also see safety factors in table 5-3.

Table 5-2. Properties of Manila and Sisal Rope.

Nominal diameter (in.)	Circumference (in.)	Weight per 100 feet (lb)	No. 1 Manila: Breaking strength (lb)	No. 1 Manila: Safe load pounds (F. S. = 4)	Sisal: Breaking strength (lb)	Sisal: Safety load pounds (F. S. = 4)
¼	¾	2.00	540	140	440	120
⅜	1⅛	4.1	1,260	320	1,020	260
½	1½	7.5	2,640	660	2,120	530
⅝	2	13.3	4,400	1,100	3,520	880
¾	2¼	16.7	5,400	1,350	4,320	1,080
⅞	2¾	18.6	7,700	1,920	6,160	1,540
1	3	27.0	9,000	2,250	7,200	1,800
1⅛	3½	36.0	12,000	3,000	9,600	2,400
1¼	3¾	41.8	13,440	3,360	10,800	2,700
1½	4½	60.0	18,500	4,620	14,800	3,700
1¾	5½	89.5	26,500	6,620	21,200	5,300
2	6	108.0	31,000	7,750	24,800	6,200
2½	7½	135.0	46,500	11,620	37,200	9,300
3	9	242.0	64,000	16,000	51,200	12,800

Note. Breaking strength and safe loads given are for new rope used under favorable conditions. As rope ages or deteriorates, progressively reduce safe loads to ½ of values given. Also see safety factors in table 5-3.

Table 5-3. Safety Factors for Ropes, Cables, and Chains

Type of service	Wire rope	Sisal or manila rope	Chain
Guy lines	3.5	3.5	3.5
Miscellaneous hoisting equipment.	5.0	7.0	5.0
Haulage lines	6.0	8.0	6.0
Overhead and gantry cranes.	6.0		
Jib and pillar cranes	6.0	...	...
Derricks	6.0	...	...
Small electric and air hoists.	7.0	...	7.0
Slings	8.0	10.0	8.0

Note. To determine the safeload for single line, divide the breaking strength of the line by the applicable safety factor, and multiply the result by an assumed efficiency factor of 80 percent for fittings.

b. Inspections. Wire rope or cables must be inspected by a competent person at the time of installation and *once each week thereafter* when in use. They must be removed from hoisting or lifting service when found to be kinked or when the number of broken wires in a strand, as measured in the distance in which one strand makes one complete turn around the rope, are as follows:

(1) When three broken wires are found in one strand of 6 x 7 wire rope.

(2) When six broken wires are found in one strand of 6 x 19 wire rope.

(3) When nine broken wires are found in one strand of 6 x 37 wire rope.

(4) When eight broken wires are found in one strand of 8 x 19 wire rope.

Wire rope removed from service due to defects must be plainly marked or identified as being unfit for further use on cranes, hoists, or for other load-carrying service.

c. Slings. Slings, their fittings and fastenings, when in use, must be inspected *daily* by a qualified person for evidence of overloading, excessive wear, or damage. Those found to be defective must be removed from use. Slings should be made by qualified personnel. All eye splices must be made in approved manner and wire rope thimbles of proper size shall be fitted in the eye, if used. Wire rope clips attached with U-bolts must have the U-bolts on the dead or short end of the rope (fig. 5-2). The U-bolts must be tightened immediately *after* initial load application *and at frequent intervals thereafter.* Table 5-4 shows the number and spacing of clips and the proper torque to be applied to the nuts of the clips. The minimum number of clips used is three.

d. Hooks and Shackles. Hooks, shackles, rings, pad eyes, and other fittings that show excessive wear or have been bent, twisted, or otherwise damaged should be removed from service. All hooks used for the support of human loads or loads that pass over workmen will be closed or moused. The use of an open hook is prohibited in rigging to lift any load where there is danger of relieving the tension on the hook due to the

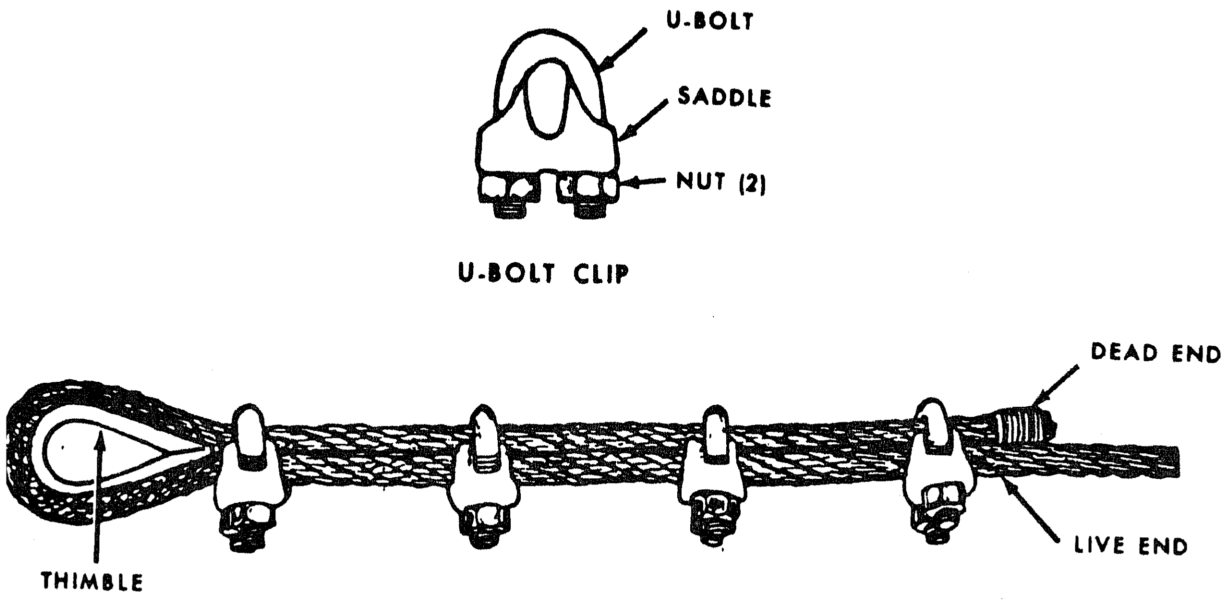


Figure 5-2. How to attach wire rope clips.

Table 5-4. Number of Clips Necessary to Assemble Wire Rope Eye Connections

Wire rope diameter (inch)	(mm)	Nominal size of clips (inch)	Number of clips	Spacing of clips (inches)	(mm)	Torque to be applied to nuts of clips (ft-lb)	(m-kg x 0.1382)
5/16	(7.95)	3/8	3	2	(60)	25	(3.5)
3/8	(9.52)	3/8	3	2¼	(57)	25	(3.5)
7/16	(11.11)	1/2	4	2¾	(70)	40	(5.5)
1/2	(12.70)	1/2	4	3	(76)	40	(5.5)
5/8	(15.85)	5/8	4	3¾	(95)	65	(9.0)
3/4	(19.05)	3/4	4	4½	(114)	100	(14)
7/8	(22.22)	1	5	5¼	(133)	165	(23)
1	(25.40)	1	5	6	(152)	165	(23)
1¼	(31.75)	1¼	5	7½	(190)	250	(35)
1 3/8	(34.92)	1½	6	8¼	(210)	375	(52)
1½	(38.10)	1½	6	9	(230)	375	(52)
1¾	(44.45)	1¾	6	10½	(267)	560	(78)

Note. The spacing of clips should be six times the diameter of the wire rope. To assemble end-to-end connection the number of clips indicated above should be increased by two, and the proper torque indicated above should be used on all clips; U-bolts are reversed at the center of connection so that the U-bolts are on the dead (reduced load) end of each wire rope.

load or hook catching or fouling. When a wedge socket type of fastening is used to fasten the load to a line, the dead or short end of the line should be clipped with a U-bolt or otherwise made secure against loosening.

5-11. Cranes

a. Primary Hazards. The primary hazards of operating cranes, clamshells, draglines, backhoes and shovels are —

(1) Dropping or slipping of load.

(2) Breaking of cables.

(3) Non-use of outriggers.

(4) Clutch or brake slipping and allowing boom radius to increase.

(5) Non-use of mousing or safety type hooks.

(6) Obstruction to the free passage of boom or the load of the crane.

(7) Backing and turning of machines without looking.

(8) Operators not being familiar with equipment.

(9) Operating on uneven ground.

(10) Boom contacting high tension wires.

(11) Use of estimated weight rather than determining actual weight of load.

(12) Not referring to capacity charts on cranes when different boom lengths are used.

(13) Use of boom with bent or dented chord members.

(14) Failure to make test lift of loads of unknown weight at least stable lifting position.

(15) Use of crane hoist cable for towing.

b. Operator Responsibility. Crane operators are responsible for knowing the limitations and capabilities of the cranes in their charge. They shall not attempt, nor shall they be required or permitted, to operate a crane in an unsafe manner or to operate a crane known to be in an unsafe condition. Operators shall promptly report any malfunctioning or other defects in the equipment. Operators shall have the authority to stop and refuse to handle loads until safety has been assured.

c. Personnel Restriction.

(1) Authorized crane operators. Cranes shall be operated only by authorized personnel who are thoroughly trained in the fundamental rules of crane safety.

(2) Climbing on moving crane. No personnel except the operators and, on occasion, examiners, supervisors, trainees, or repairmen, shall be permitted on the crane while it is in operation. No more than three such persons shall be in the cab at any time while the crane is in operation. No one shall ever climb on or off a moving crane.

d. Lifting Load from Water. When lifting a load from water, its condition should be noted carefully. Contained water, or water in a water-logged structure, should be computed as a part of the weight. When the load leaves

the water the crane takes on the added load as its buoyancy is lost. Unknown weights should never be lifted from the water. Waterlogged loads or loads from water or mud should never be handled unless expressly authorized by an officer or supervisor qualified to determine the capability of the crane to handle the load.

e. Testing Load. When a heavy load is to be handled, the load shall first be raised a few inches to find out whether or not there is undue stress on any part of the sling and to make sure that the load is well balanced. If anything is found to be wrong with the brake or engine, or with the adjustment of the sling, the load shall be lowered at once and no attempt made to move it again until the necessary adjustment or repairs have been made.

f. Testing Brakes. When lifting a capacity load, the brakes should be checked by stopping the lift a few inches above the ground and holding it with the brake. After rains, or under certain atmospheric conditions, brake linings may be wet and may not be fully effective until they have dried out. Operators should test brakes at the beginning of a new shift, after a rain storm, or at any time it is reasonable to suspect that brake linings may have become wet.

g. Hoisting Line Vertical. Before lifting a near-capacity load, operators must be sure the hoisting line is vertical. They should move the crane to position rather than lower the boom; a swinging capacity load increases the chance of tipping. They should never try to lift tied-down loads, or pull pipes or other objects out of the ground.

h. Lowering Boom. Lowering of the boom under load shall be done only with the greatest caution, checking the radius-load capacity chart, and radius indicator where necessary. Lowering the hoist line and the boom simultaneously shall never be done.

i. Speed of Lowering. When lowering loads, the speed should be limited; it should not exceed the hoisting speed of the equipment for the same load. The ordinary hoisting speed of a 30-ton motor-operated crane is about 18 feet per minute with rated load. Stopping the load at such speeds within a short distance may double the stress on the slings and crane.

j. Swinging Loads. Care shall be exercised continuously to guard other workmen, buildings, or scaffolds against injury from swinging loads. Loads should not be swung over workmen. If it is absolutely necessary to move loads over space with personnel working below, adequate warning must be given by bell or siren so the workmen can move into safe places.

k. Dual Lifts. Dual lifts are extremely dangerous and should be attempted only when absolutely necessary, and then only under competent supervision throughout the entire operation. Before making a dual lift the proper position of the cranes and the location of the slings to balance the load properly for each crane should be carefully determined. Shifting of the load would cause overloading and failure of one crane, thus throwing the entire load onto the second crane and resulting in the failure of both cranes.

l. Fire Extinguishers. All cranes shall be equipped with appropriate fire extinguishers which shall be maintained ready for use.

m. Damaged Crane Boom. When repairs or alterations are made to any part of a crane or derrick involving its hoisting capacity or margin of stability, the crane or derrick shall be tested by a competent person and a written statement specifying the safe working load shall be issued.

5-12. Piledrivers

In setting up for piledriving operations, suitable guys, outriggers, thrustouts, counterbalances, or rail clamps must be provided as necessary to maintain stability of the rig. In operation, a safety lashing should be provided for all hose connections to piledrivers, pile ejectors, or jet pipes, and taglines should be used for controlling "unguided piles" and "flying hammers". When hoisting steel piling, a closed shackle or other positive means of attachment should be used. Only piledriving crew members and necessary authorized persons should be per-

mitted in the actual work areas during driving operations.

a. Hammer and Driving Heads. When a pile driver is not in use the hammer shall be held in place at the bottom of the leads by a cleat or timber. Driving heads shall be tied-in whenever the rig is being used to shift cribbing or other material.

b. Making Repairs. Repairs shall never be made to any diesel or air equipment while it is in operation or under pressure.

c. Defective Air Hose. When compressed air equipment is used, defective air hose shall be promptly replaced. Inspections should be made frequently to locate defects.

d. Overhead Wires. Care must be exercised to see that the high parts of the pile driver do not come in contact with overhead electric power lines when the equipment is moved.

e. Drums, Brakes, and Leads. Hoisting drums and brakes shall be kept in the best of condition and sheltered from the weather. Leads shall be kept well greased to provide for perfectly smooth travel of the hammer.

f. Danger from Hammer. A workman shall never place his head or other part of his body under a suspended hammer that is not dogged or blocked in the leads.

5-13. Power Shovels

a. Removing Shovel for Repairs. In case of a breakdown, the shovel should be moved well away from the foot of a slope before repairs are undertaken.

b. Range of Swing. All persons *must* keep away from the range of the shovel's swing, to avoid being struck by the cab as it rotates. When workmen are required to do some particular work at the rear of the cab of a shovel, they should notify the operator that they are working there.

c. Replacing Wire Cables. The wire rope cables on power shovels shall be regularly inspected and shall be changed when 10 percent of the wires in any 3 feet of length are broken.

d. Leaving Cab. Shovel operators shall not leave the cab while the master clutch is engaged.

e. Leaving Bucket on Ground. All shovels when not in use shall be left with the bucket on the ground.

f. Clearing Overhead Wires. Whenever it is necessary to move the shovel under electric wires, there shall be a clearance of at least 10 feet. All necessary precautions shall be taken to prevent contact with the wires.

g. Grounding. Power shovels should be effectively grounded and otherwise protected against the hazards of static electricity.

h. Ramps. Ramps to be used by power shovels should not be made too steep. The brakes and travel mechanisms should be checked before traversing ramps.

i. Slides. When excavating in a bank of sand, gravel, or rocks which have been dynamited, shovel operators must be very careful not to cause a slide by digging the shovel too far into the bank or making cuts too deep.

j. Shovel as Refuge. When blasting, the shovel shall not be used as a safety refuge.

k. Leaving Cab While Loading. Drivers shall not remain in the seat or cab of a dump truck which is being loaded by a power shovel, a clam shovel, drag line, or other overhead means, even if the truck top is equipped with a steel protective shield. They shall always set the brakes, leave the cab, and remain outside the reach of the swing of the bucket until the truck has been loaded.

5-14. Scoop Loaders

Loaders must be operated with caution as they are easy to turn over. On clark Model Loaders caution must be exercised not to extend any portion of the body between the cab and raised bucket arms. The primary hazards of operating scoop loaders are gound in the following unsafe practices:

a. Bucket not blocked when being work on.

b. Lack of caution when removing and replacing lock ring on tires.

c. Working between wheels and frame when engine is running.

d. Operating too close to edge of trench when backfilling.

e. Digging into banks or stockpiles, creating overhangs and working under them.

f. Riding with bucket too high when traveling; 15 inches is good carry height.

g. Carrying passengers in the bucket of the loader.

h. Forgetting to ground the bucket or set the parking brake before leaving the machine.

5-15. Forklifts

a. Overhead Safety Guards. Forklift trucks of all types will be equipped with an overhead safety guard fabricated from steel. Exceptions will be permitted only when the overhead safety guard would either increase the overall height of the fork truck or prevent the operator from having freedom of movement.

b. Load Capacity. The load capacity and gross weight of each forklift shall be stenciled on the machine in plain view of the operator. This capacity shall never be exceeded. Counterweighting of machine to increase lifting capacity is prohibited. Capacity shall be rated at 24 inches from heel of forks.

c. Facing Forward. Operators shall always face in the direction of travel. All loads shall be carried in such a manner that operator's vision is unobstructed in direction of travel.

d. Ramps and Grades. Forklifts transporting cargo up ramps or other grades shall be operated with the load up grade; carrying cargo down grade shall be done by backing down grade with the load up grade.

e. Channel Tipped. All loads being transported shall be carried with tines tipped back.

f. Hoisting Personnel. Forklifts shall be used to hoist personnel only under the following conditions:

(1) Supervisor shall authorize all raising and lowering of personnel by forklifts.

(2) Special "personnel pallets" with guard rails on four sides shall be used.

(3) During actual raising and lowering operation, all personnel shall face away from mast and keep hands clear of hoisting mechanism.

(4) Personnel shall never be transported in an elevated position.

(5) Only skilled personnel shall be asked to perform tasks requiring elevation by fork trucks.

g. Lifting Vehicles. Slings or lifting pads shall never be attached to the overhead guards for the purpose of lifting the vehicle.

h. Nonoperating Position. When not in operation, the forks shall be lowered and rested flat on the floor.

5-16. Fueling of Equipment

All motor vehicles and mechanized equipment using gasoline shall be shut down with ignition off prior to and during refueling operations.

5-17. Loading of Equipment

When vehicles such as trucks or earth haulers are being loaded the driver or operator must leave the cab when exposed to danger from suspended or overhead loading equipment or methods. Loads must be placed so as not to obscure the driver's vision ahead or to either side, or to interfere in any manner with the safe operation of the vehicle. They must be properly distributed, chocked, tied down or otherwise secured. Loads should not extend beyond the sides of the vehicle except under emergency circumstances, and then such warnings and precautions will be taken to prevent endangering passing traffic or damage to the vehicle.

5-18. Excavations

Excavations, if over four feet in depth, unless in solid rock, hard shale, hardpan, cemented sand and gravel, or other similar materials, shall be either shored, sheeted and braced, or sloped to the angle of response. All shoring and bracing shall be designed so that it is effective

to the bottom of the excavation. Sheeting, sheet piling, bracing, shoring, trench boxes, and other methods of protection, including sloping, shall be based upon calculation of pressures exerted by and the condition and nature of the materials to be retained, including surcharge imparted to the sides of the trench by equipment and stored materials. Additional precautions by way of shoring and bracing must be taken to prevent slides, or cave-ins when excavations or trenches are made in locations adjacent to backfilled excavations or subjected to vibrations from traffic or vehicles, from the operation of machinery, or from any other source. Trenches, ditches, and similar gaps over which men or equipment are required or permitted to cross, must be provided with walkways or bridges with guardrails.

APPENDIX

REFERENCES

1. Army Regulations

AR 58–1	Joint Procedures for Management of Administrative Use Motor Vehicles.
AR 385–55	Prevention of Motor Vehicle Accidents.
AR 600–55	Motor Vehicle Driver-Selection, Testing, and Licensing.
AR 600–58	Mechanical Equipment Operation-Selection, Testing, and Licensing.

2. Field Manuals

FM 5–1	Engineer Troop Organizations and Operations.
FM 5–34	Engineer Field Data.
FM 5–142	Nondivisional Engineer Combat Units.
FM 5–162	Engineer Construction and Construction-Support Units.
FM 21–60	Visual Signals.

3. Technical Manuals

TM 5–258	Pile Construction.
TM 5–331E	Utilization of Engineer Construction Equipment, Volume E—Engineer Special Purpose and Expedient Equipment.
TM 5–332	Pits and Quarries.
TM 5–333	Construction Management.
TM 21–305	Manual for Wheeled Vehicle Driver.

4. Corps of Engineers Manual

EM 385–1–1	General Safety Requirements.

INDEX

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